

# Similarity Assessment of NLDAS Model Outputs for Drought Estimation

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The **North American Land Data Assimilation System (NLDAS)** is a collaborative project between NOAA/NCEP and NASA/GSFC, and is supported by the NOAA Climate Program Office's Modeling Analysis, Predictions, and Projections (MAPP) Program.

**Acknowledgements:** Grey Nearing, Augusto Getirana, Jim Geiger, and numerous members of both the NLDAS and LIS teams over the last 15+ years

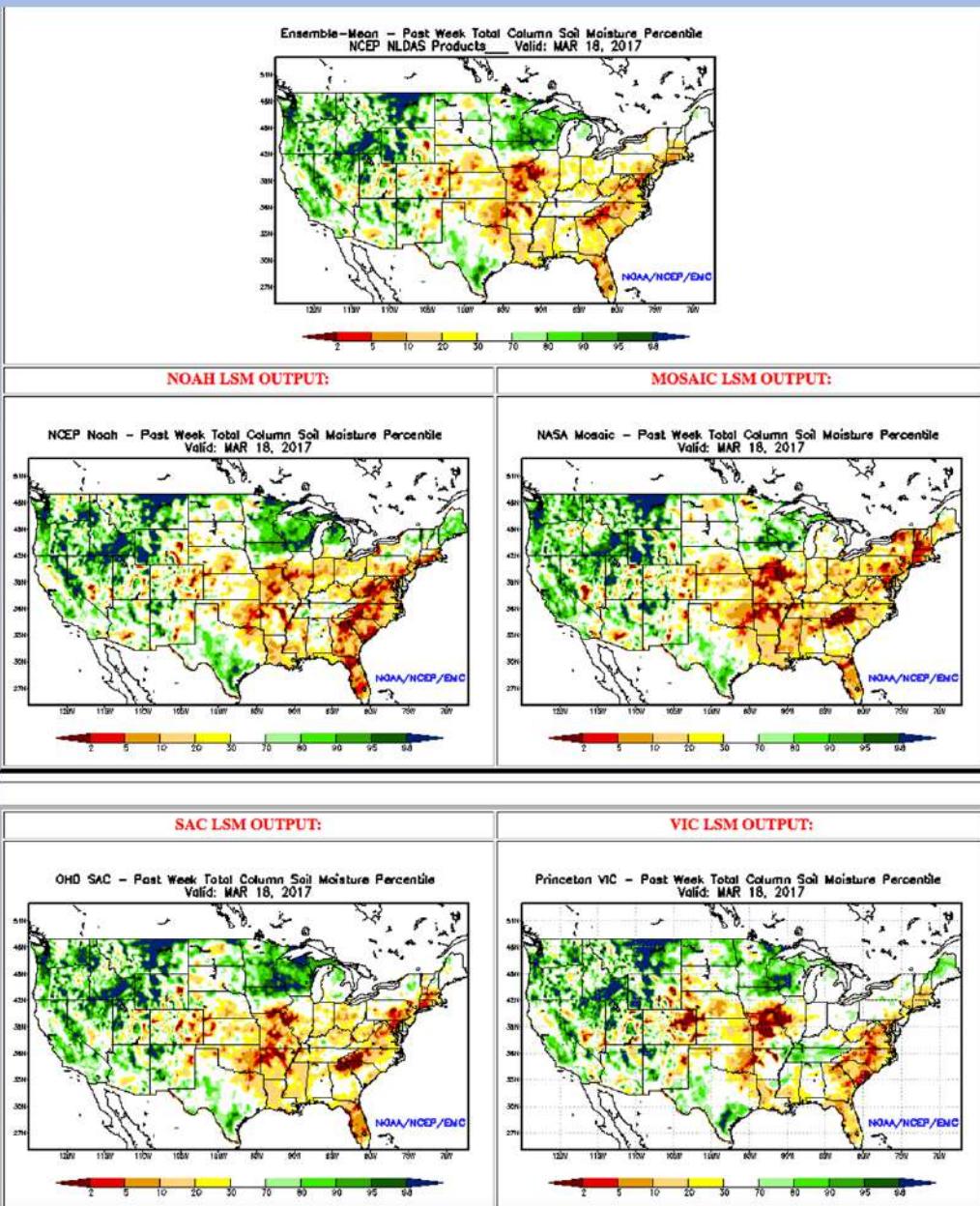
1 – NASA/GSFC; 2 – SAIC; 3 – NOAA/NCEP/EMC; 4 – IMSG

# Overarching question:

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What is the value of each model to the ensemble when monitoring drought?

# Current NLDAS Drought Monitor



- Four LSMs are run operationally at NOAA/NCEP for NLDAS Phase 2
  - Noah, Mosaic, SAC, and VIC
- The NLDAS webpage at NCEP hosts the NLDAS Drought Monitor, which is updated daily, currently with a ~4-day latency.
- Anomalies and percentiles of soil moisture (top 1-meter and total column), precipitation, evapotranspiration, SWE, runoff, and routed streamflow are provided.
- The 4 LSM ensemble mean is also shown.

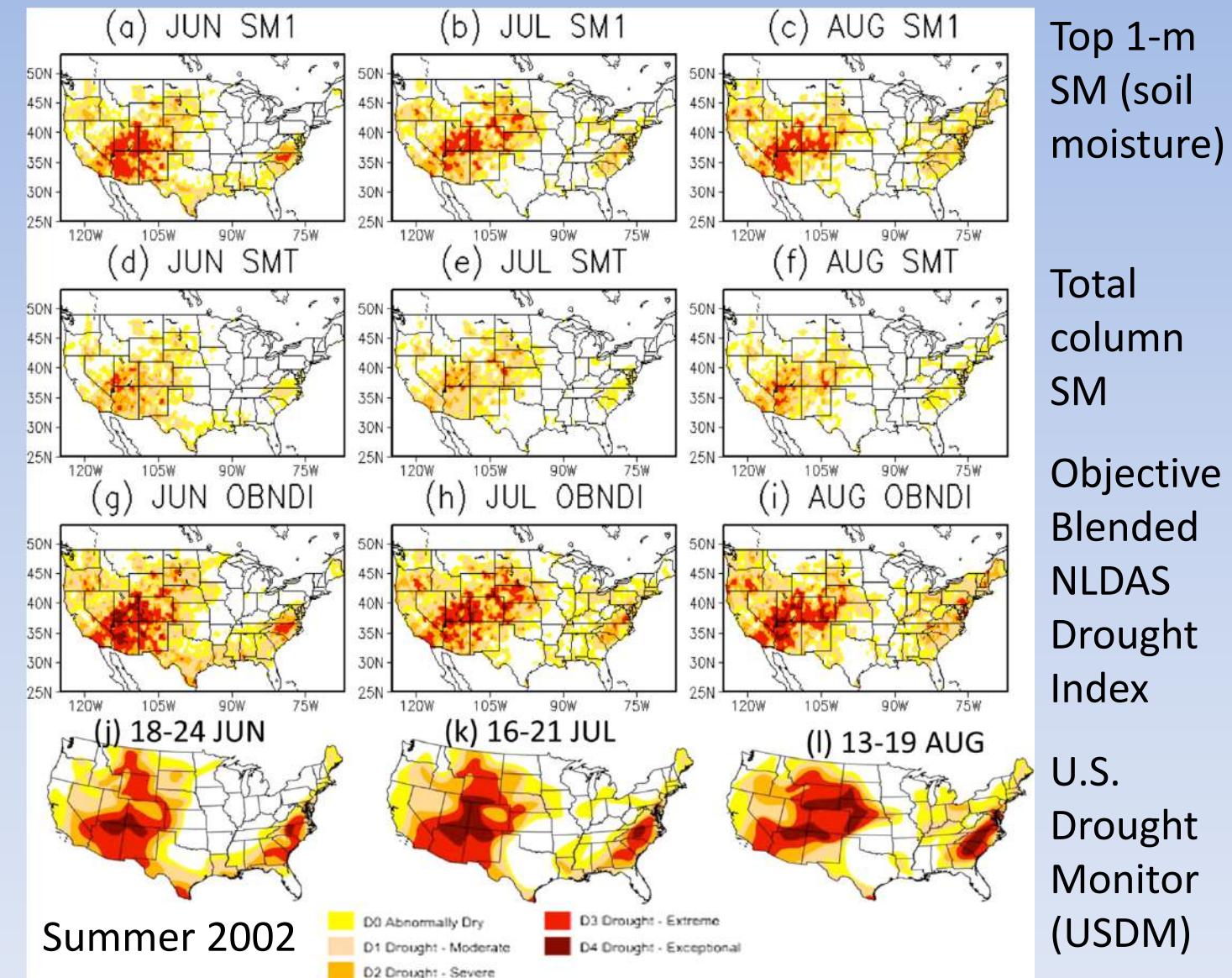
<http://www.emc.ncep.noaa.gov/mmb/nldas/drought/>

# Objective Blended NLDAS Drought Monitor

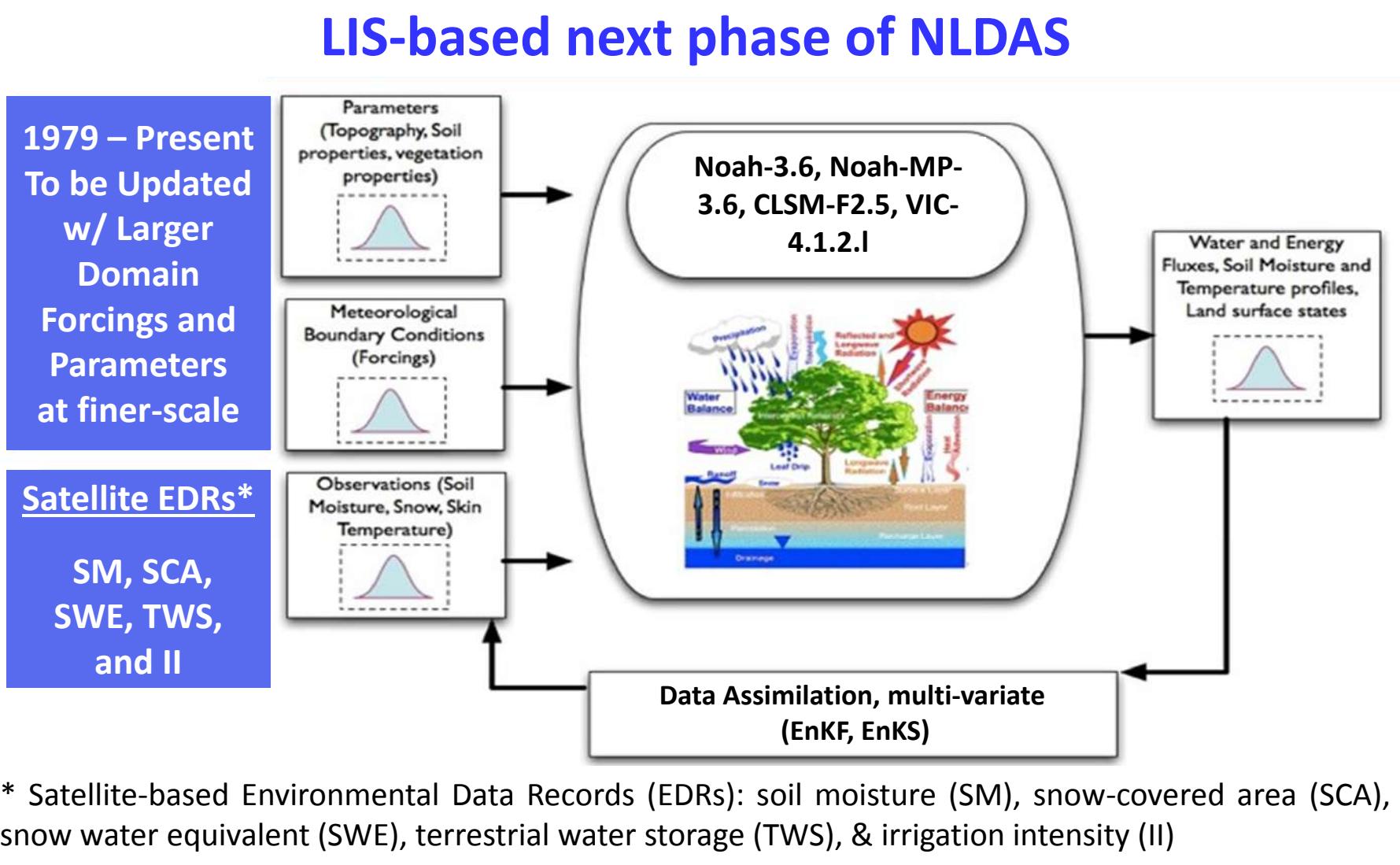
Objective blended percentiles from the ensemble-mean of the four NLDAS-2 operational LSMs were calculated using weights of different variables using training against USDM (U.S. Drought Monitor) weekly drought percentages. Weights that were calculated varied by region and by season.

Variables included in the blending:

- Top 1-meter soil moisture
- Total column soil moisture
- Evapotranspiration
- Total runoff
- Precipitation



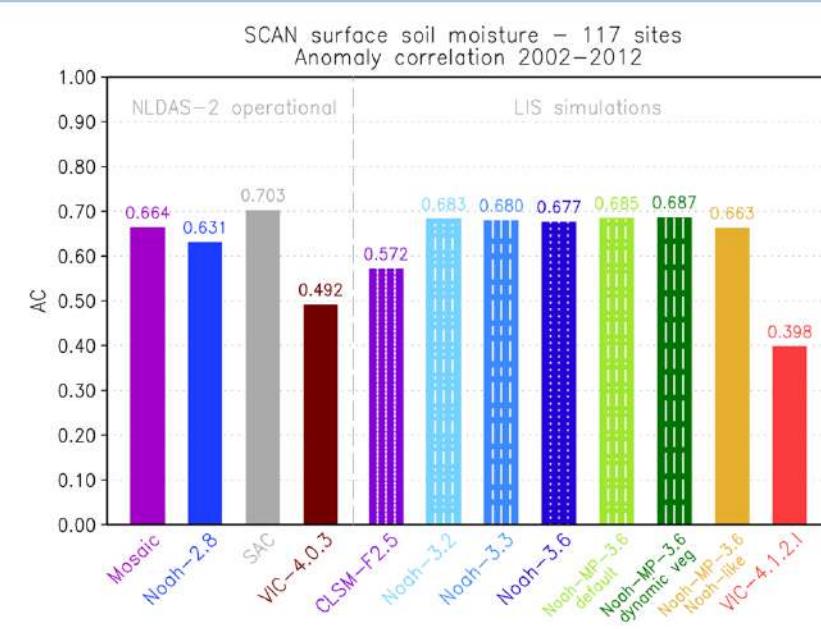
# The next phase of NLDAS will use updated models and data assimilation using NASA's Land Information System



The **Land Information System (LIS)** is a flexible land-surface modeling and data assimilation framework developed with the goal of integrating satellite- and ground-based observed data products with land-surface models.

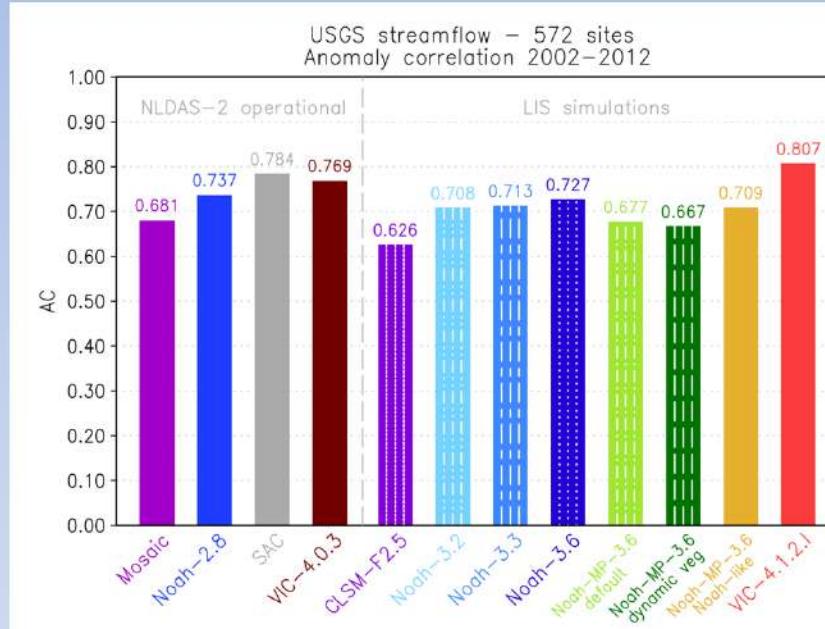
# NLDAS Science Testbed evaluation

The new and upgraded LSMs for the next phase of NLDAS have been run using the LIS software framework, and the new results and the NLDAS-2 operational LSMs have been evaluated against observations using the LVT software.

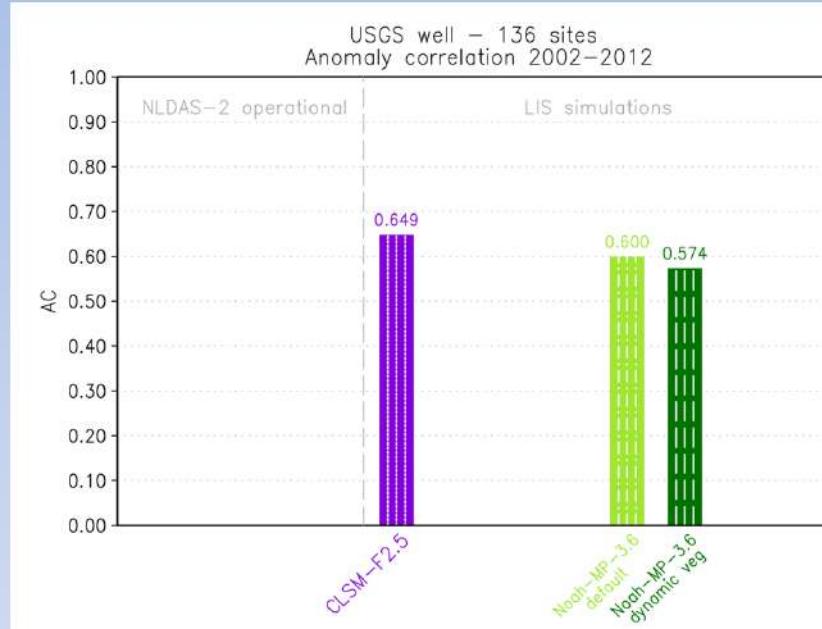


## Surface soil moisture

Anomaly correlations are shown for the 4 NLDAS-2 LSMs (left of the dashed line) and various instances/options of the LIS LSMs (right of the dashed line). Against 117 quality-controlled SCAN soil moisture sites (left panel), the new versions of Noah and Noah-MP are improved over NLDAS-2's Noah. For routed streamflow (middle) against USGS observations at 572 small, unregulated basins, the LSMs do well, particularly the new version of VIC. Groundwater anomaly correlation is shown (right) against 136 USGS well observations. Groundwater is not available in any of the NLDAS-2 LSMs, while two of the new LSMs in LIS calculate groundwater. Fluxes, snow, TWS are also in evaluation.



## Streamflow

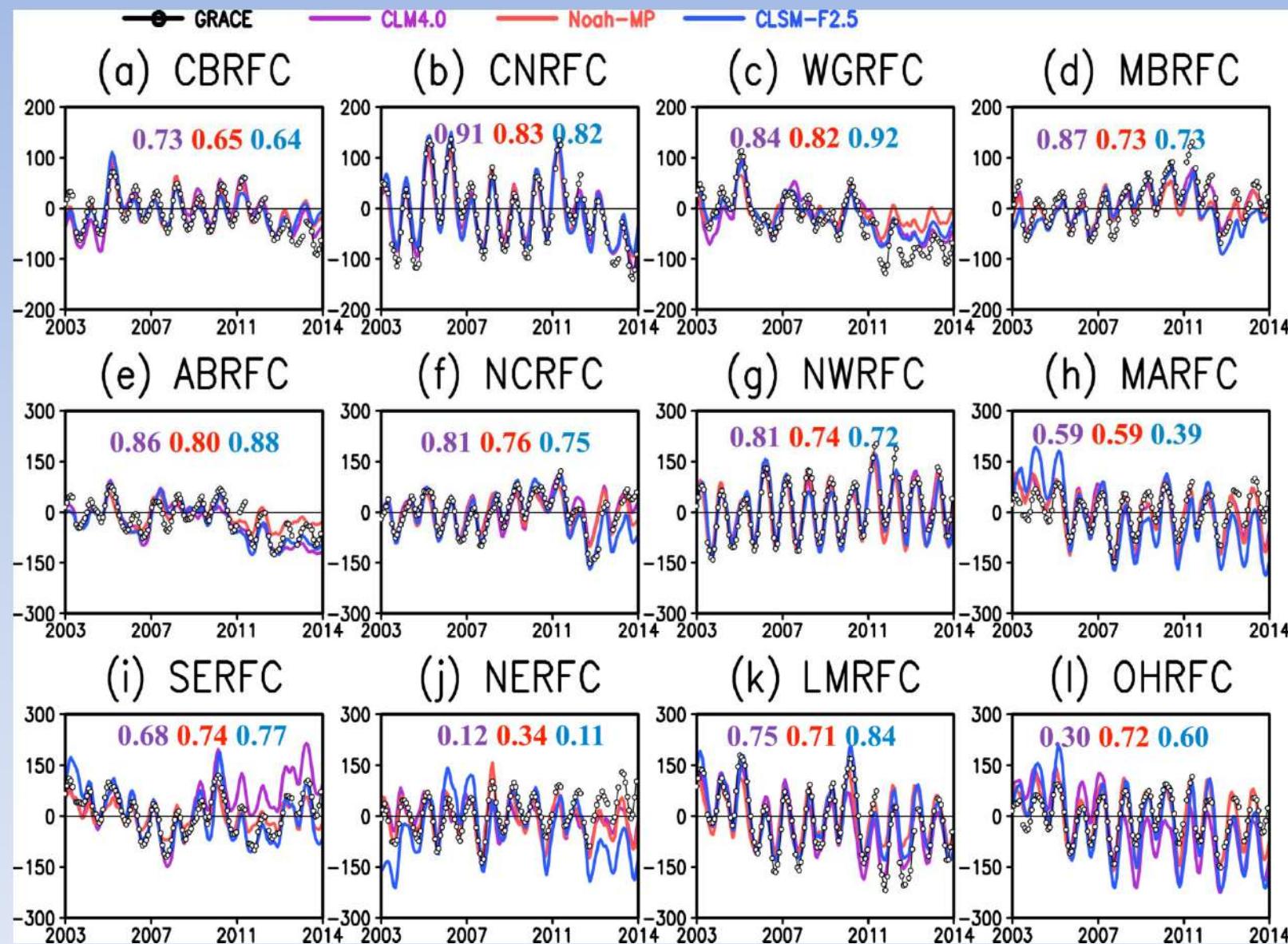


## Groundwater

# Comparison of TWS against GRACE observations

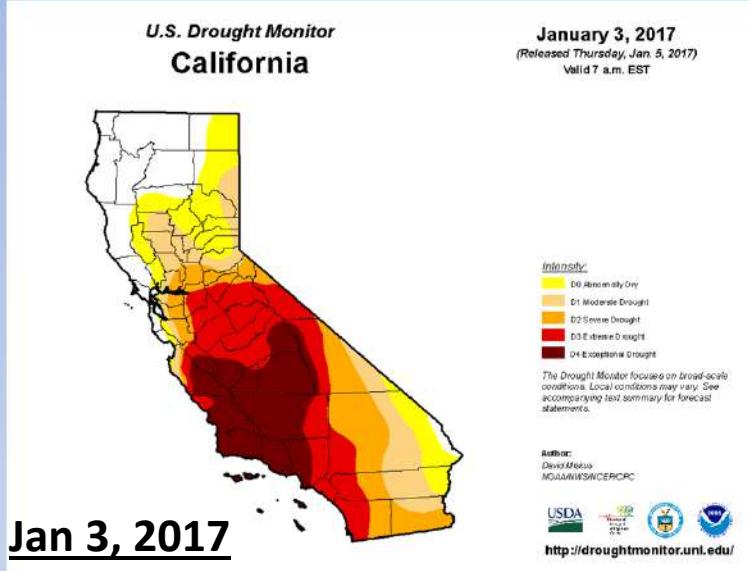
Noah-MP-3.6 and CLSM-F2.5 within LIS were evaluated for various terrestrial water storage (TWS) components (including groundwater) against CLM-4.0 LSM. This figure compares GRACE TWS anomalies for various River Forecast Centers (RFCs) in the NLDAS domain.

The CLM-4.5 LSM has been integrated into LIS and work is underway to run and evaluate it for the NLDAS Science Testbed.

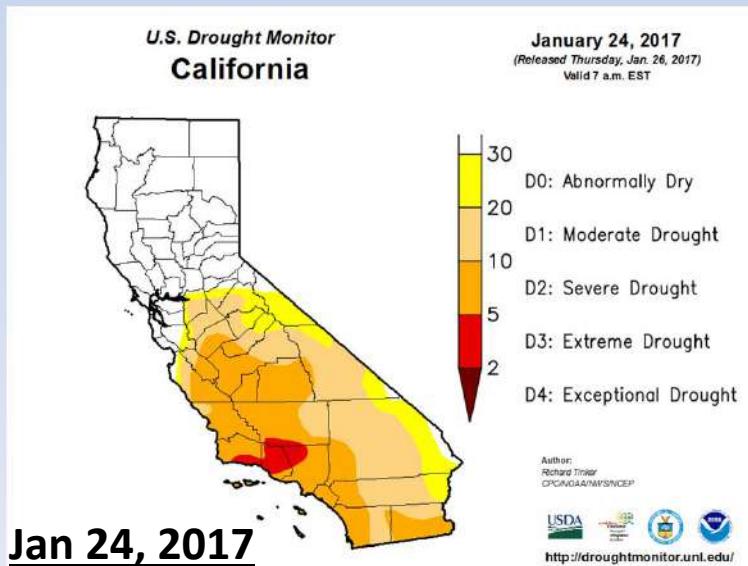


# California winter drought recovery 2016-2017

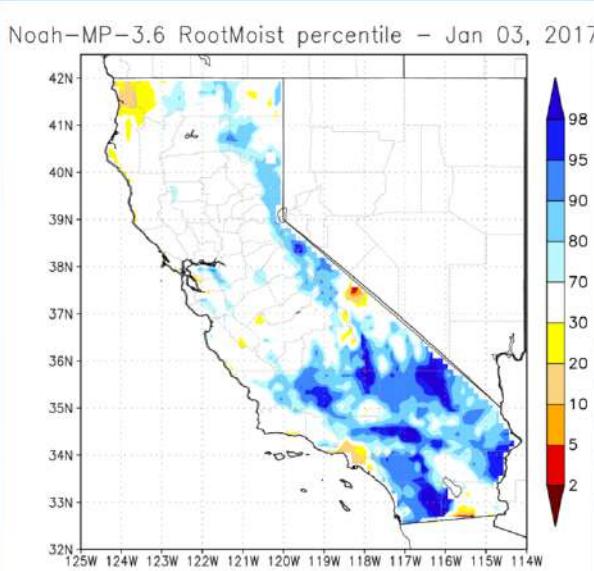
Comparisons to the U.S. Drought Monitor on Jan 3 and Jan 24, 2017 are shown. The percentiles of groundwater from Noah-MP in LIS show dryness despite many winter storms. The USDM noted the dry groundwater well observations in many areas of Southern California in issuing the USDM maps for these dates. The root zone soil moisture percentiles do not tell the entire story.



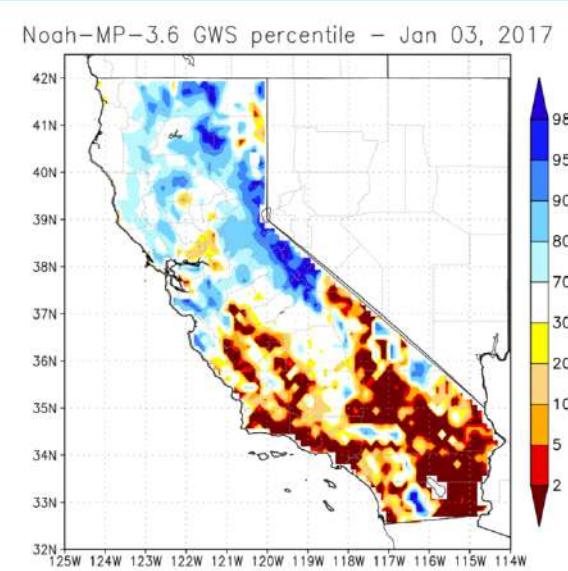
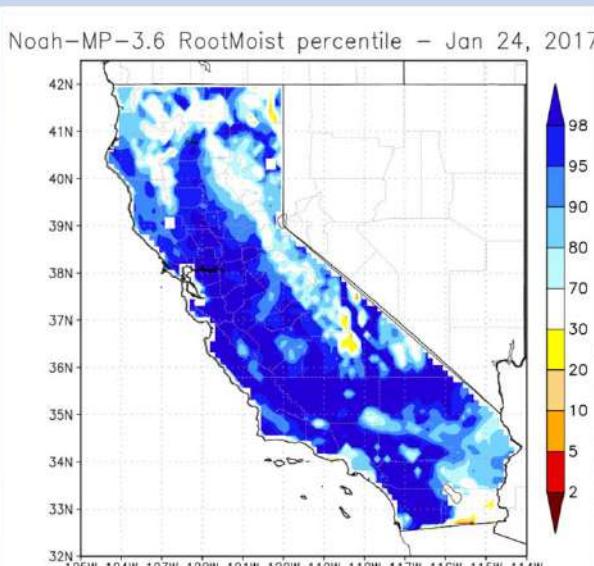
**U.S. Drought Monitor**



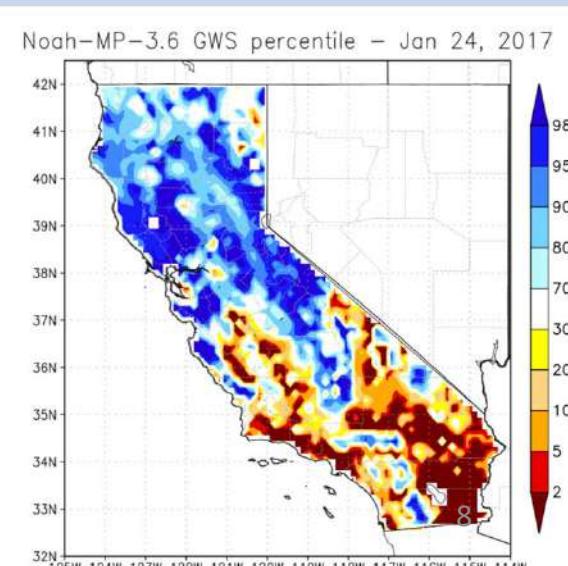
**Jan 24, 2017**



**LIS Noah-MP Root Zone SM**



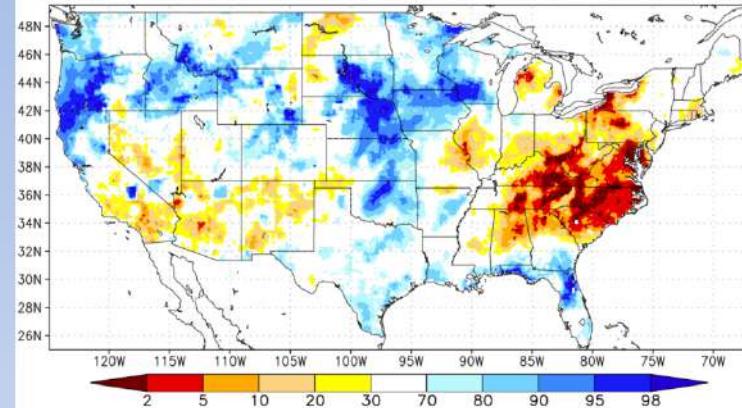
**LIS Noah-MP Groundwater**



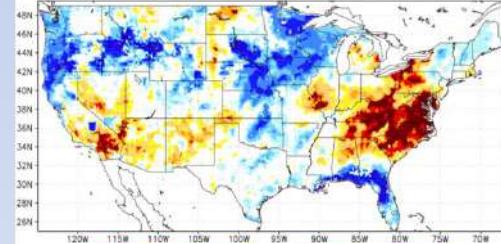
# Oct 23, 2007 – Southeast Drought

## NLDAS-2 operational LSMs

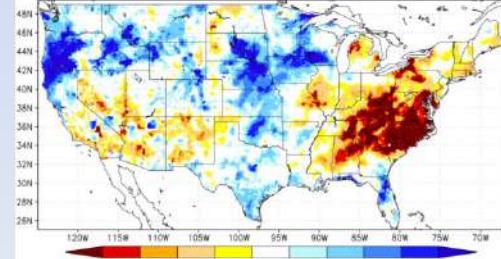
NLDAS-2 ensemble mean RootMoist percentile – Oct 23, 2007



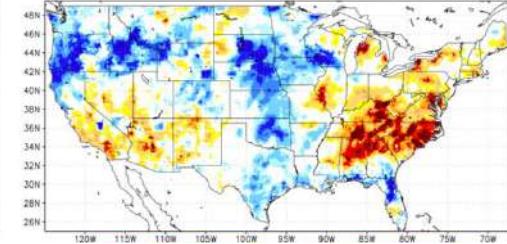
Noah-2.8 RootMoist percentile – Oct 23, 2007



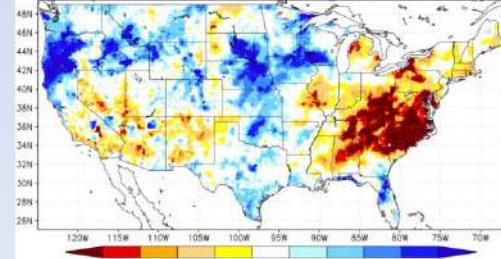
SAC RootMoist percentile – Oct 23, 2007



Mosaic RootMoist percentile – Oct 23, 2007

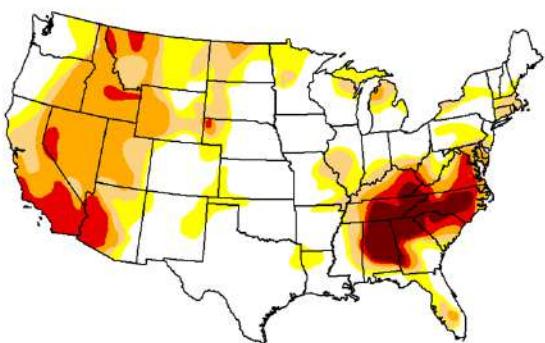


VIC-4.0.3 RootMoist percentile – Oct 23, 2007



U.S. Drought Monitor  
CONUS

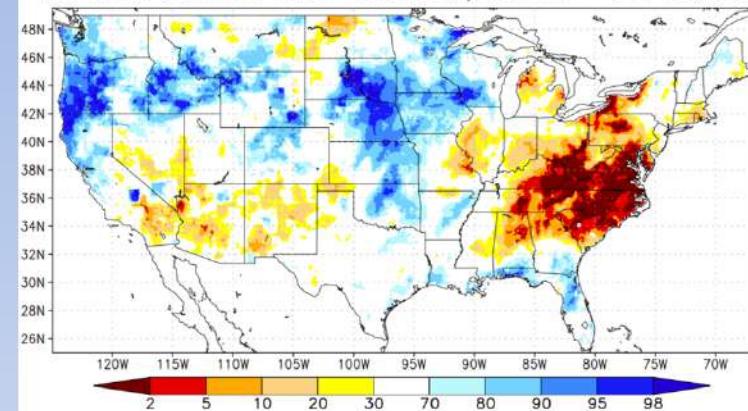
October 23, 2007  
(Released Thursday, Oct. 25, 2007)  
Valid 7 a.m. EST



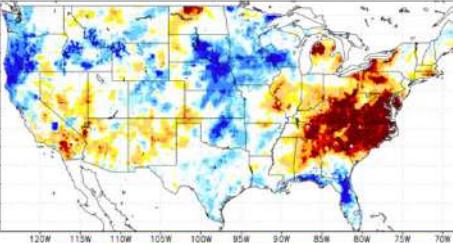
Author:  
Mark Svoboda  
National Drought Mitigation Center  
  
USDA   
<http://droughtmonitor.unl.edu/>

## LIS LSMs for next phase

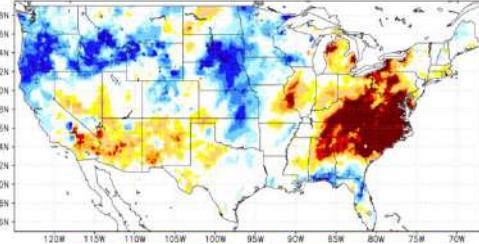
New LSMs ensemble mean RootMoist percentile – Oct 23, 2007



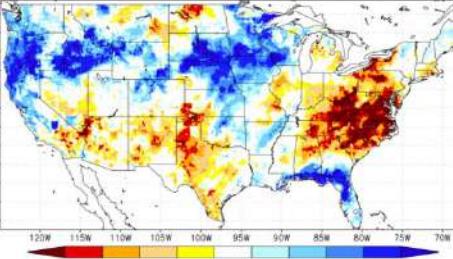
Noah-3.6 RootMoist percentile – Oct 23, 2007



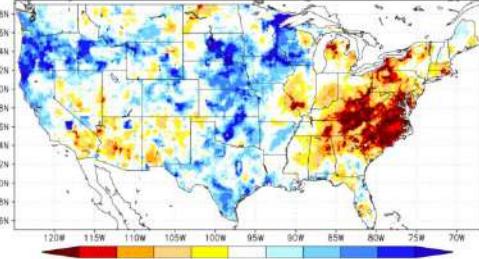
CLSM-F2.5 RootMoist percentile – Oct 23, 2007



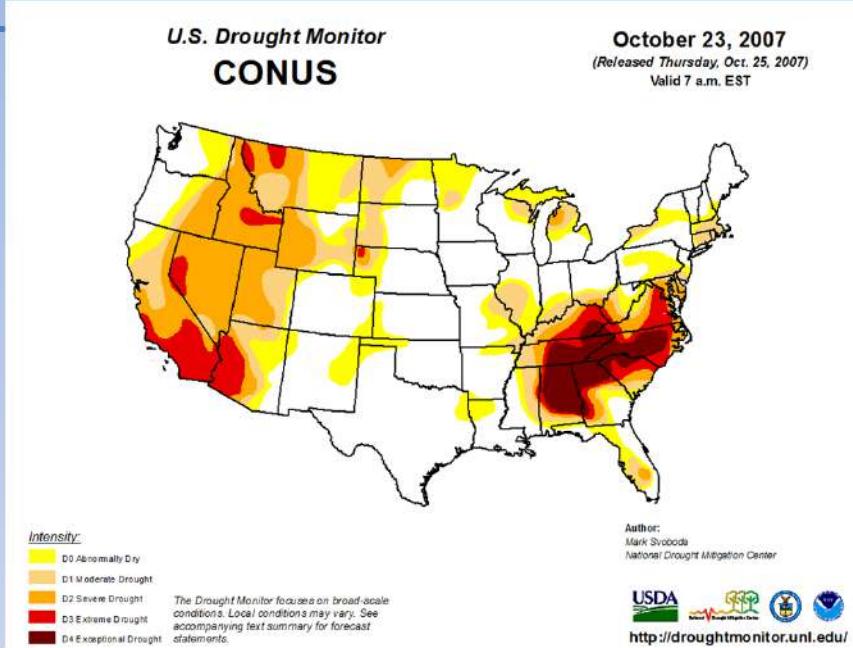
Noah-MP-3.6 RootMoist percentile – Oct 23, 2007



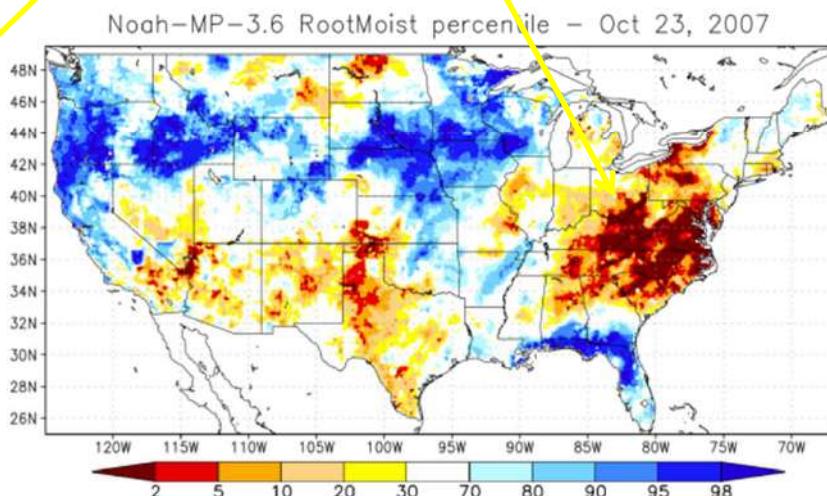
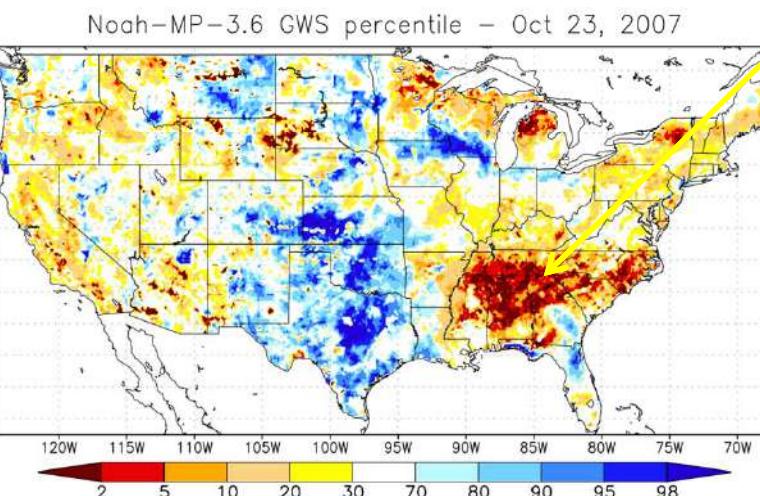
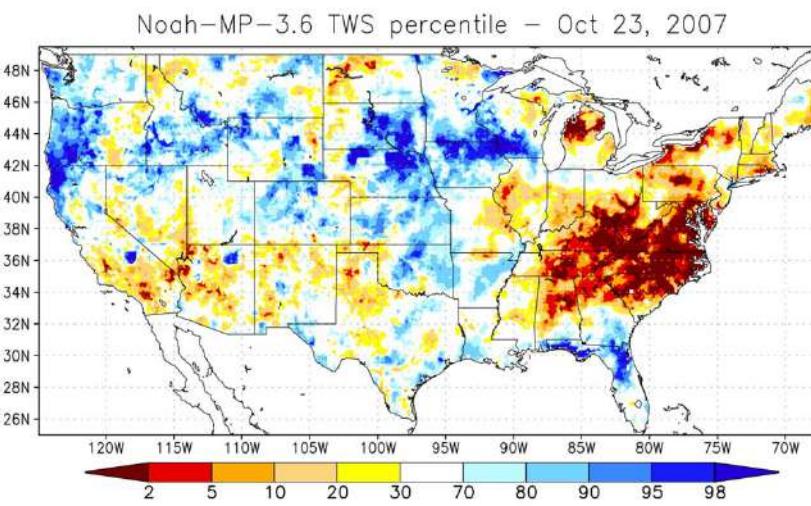
VIC-4.1.2J RootMoist percentile – Oct 23, 2007



# Oct 23, 2007 – Southeast Drought

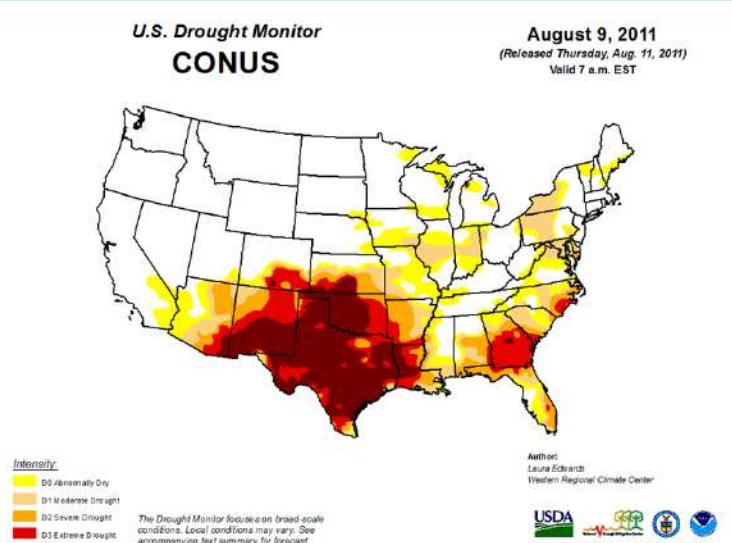
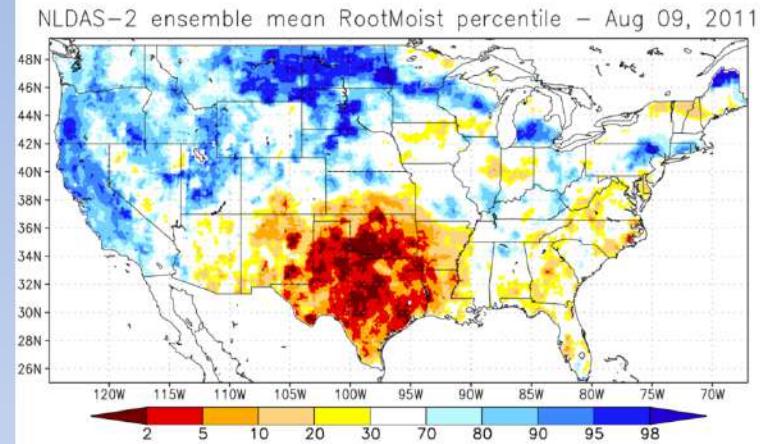


Complimentary GW and 1-m SM percentiles yield greater drought area

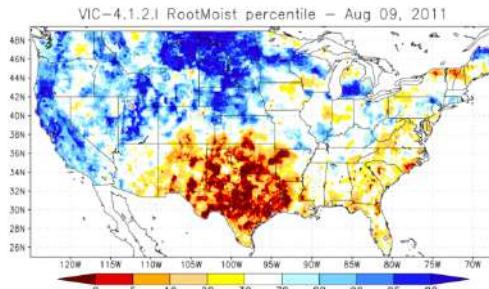
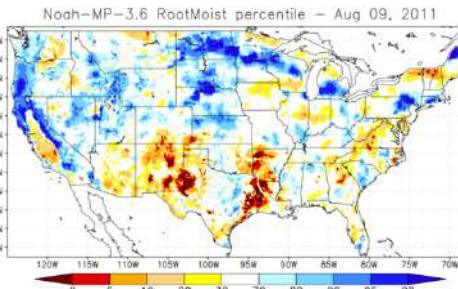
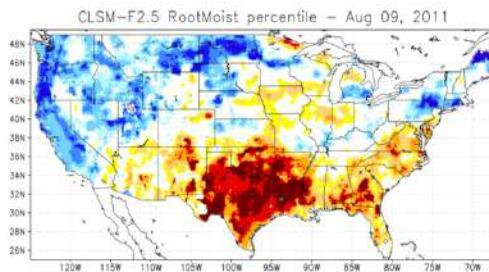
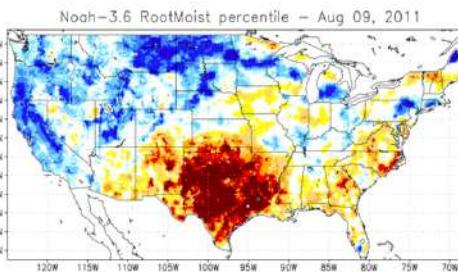
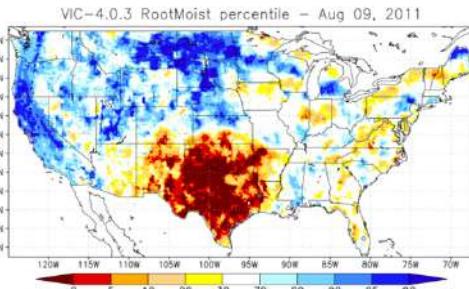
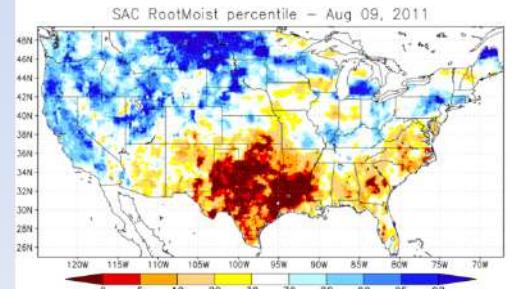
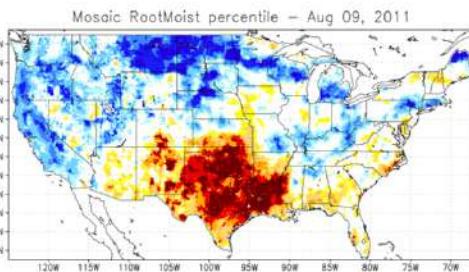
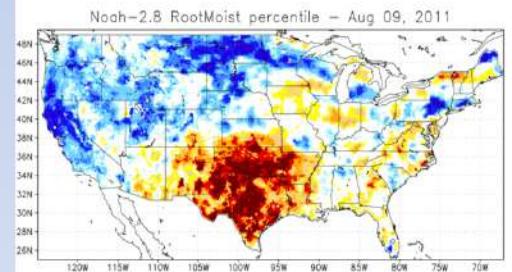
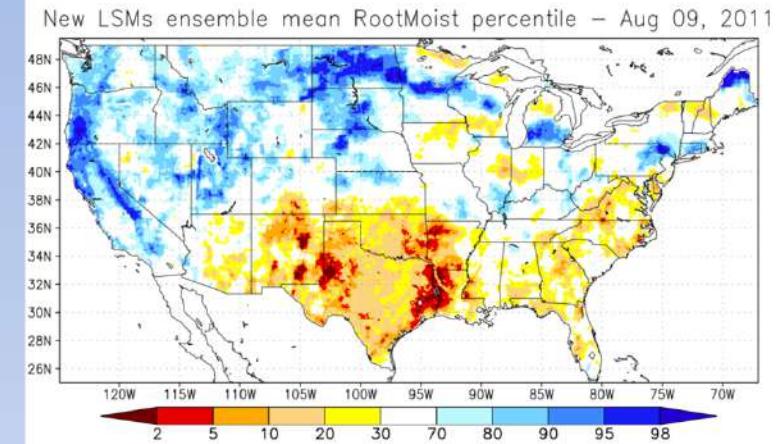


# Aug 09, 2011 – Texas Drought

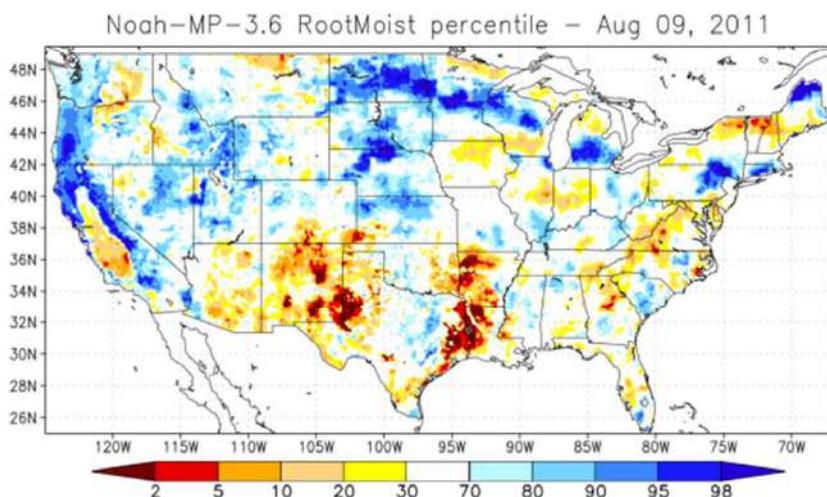
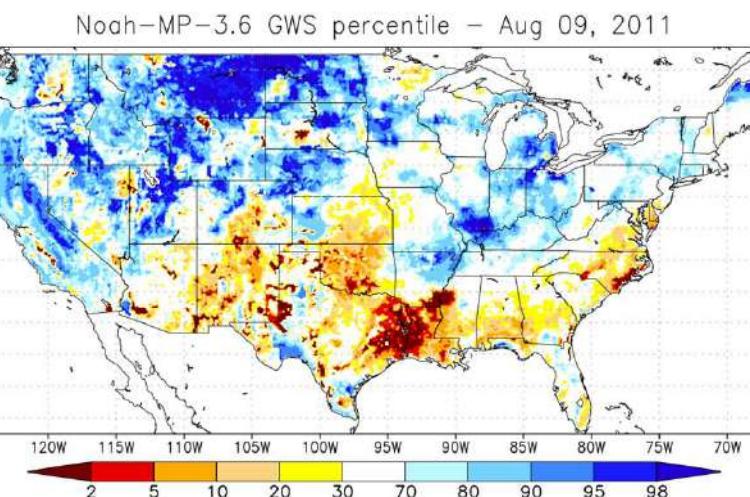
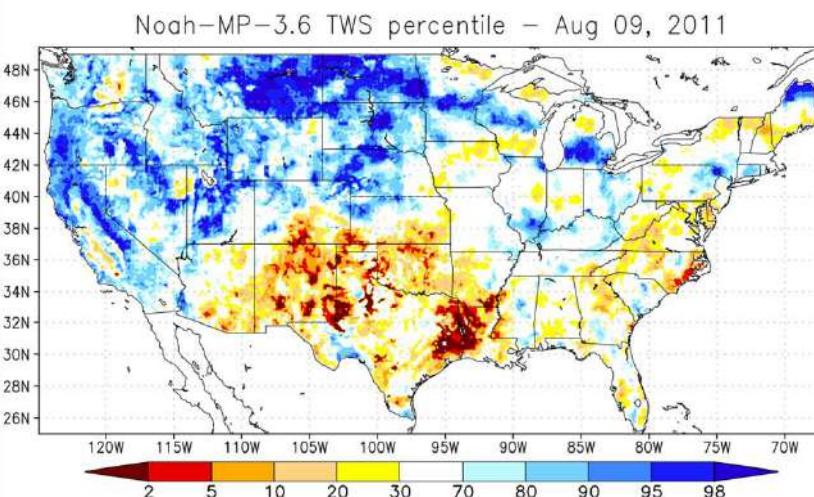
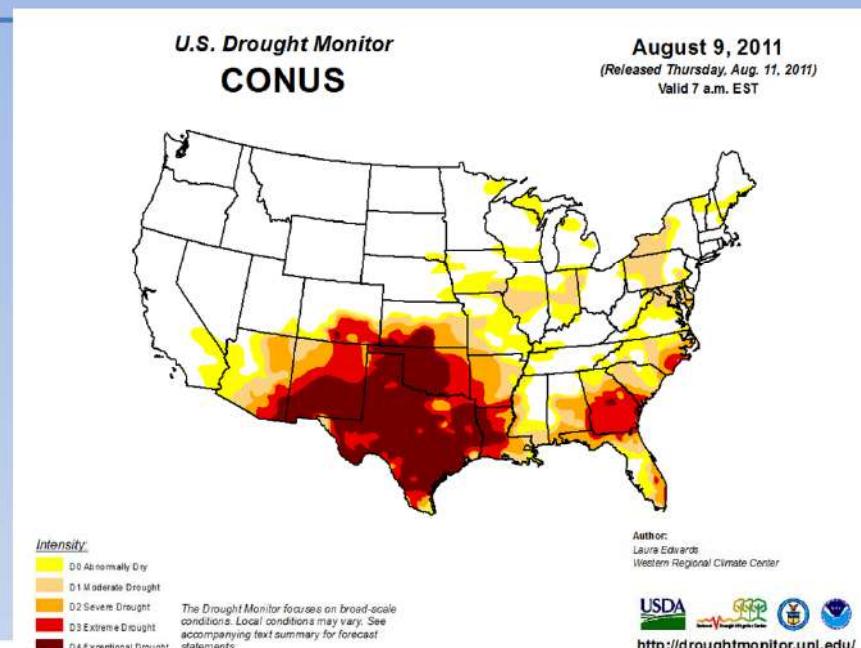
## NLDAS-2 operational LSMs



## LIS LSMs for next phase



# Aug 09, 2011 – Texas Drought

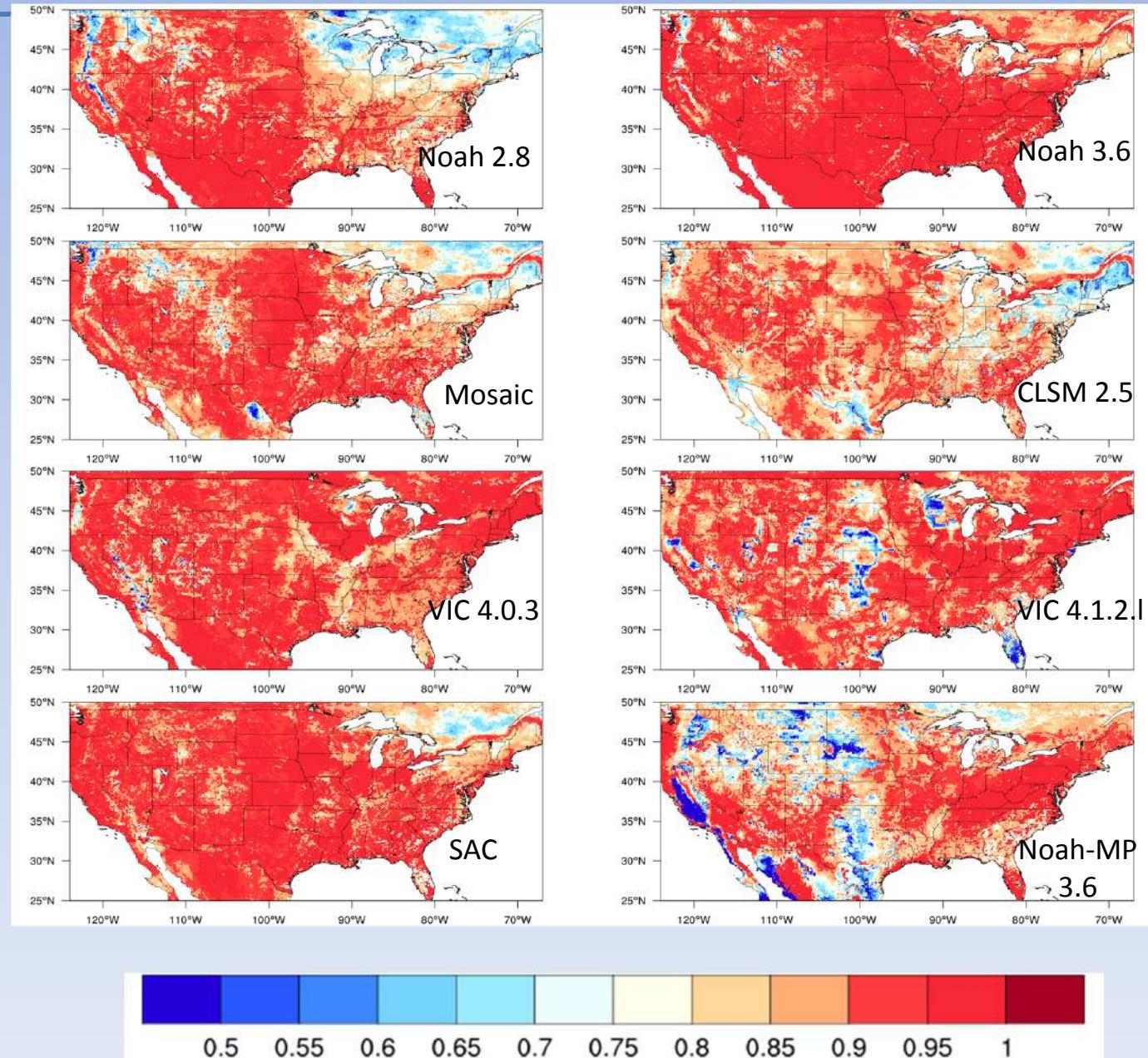


# Daily factor loading of top 1-m SM percentiles

These figures show the similarity of the top 1-meter soil moisture percentiles over a 38-year period. Values close to one indicate that that particular LSM is similar to the common factor of all 8 of the LSMs.

There are some differences amongst the models (particularly in the Northeast and in parts of the Great Plains), but there is much more similarity in the soil moisture percentiles.

Noah-MP-3.6 often shows the most dissimilarity, particularly in areas with a deep groundwater storage (California Central Valley, West Texas, Great Plains).

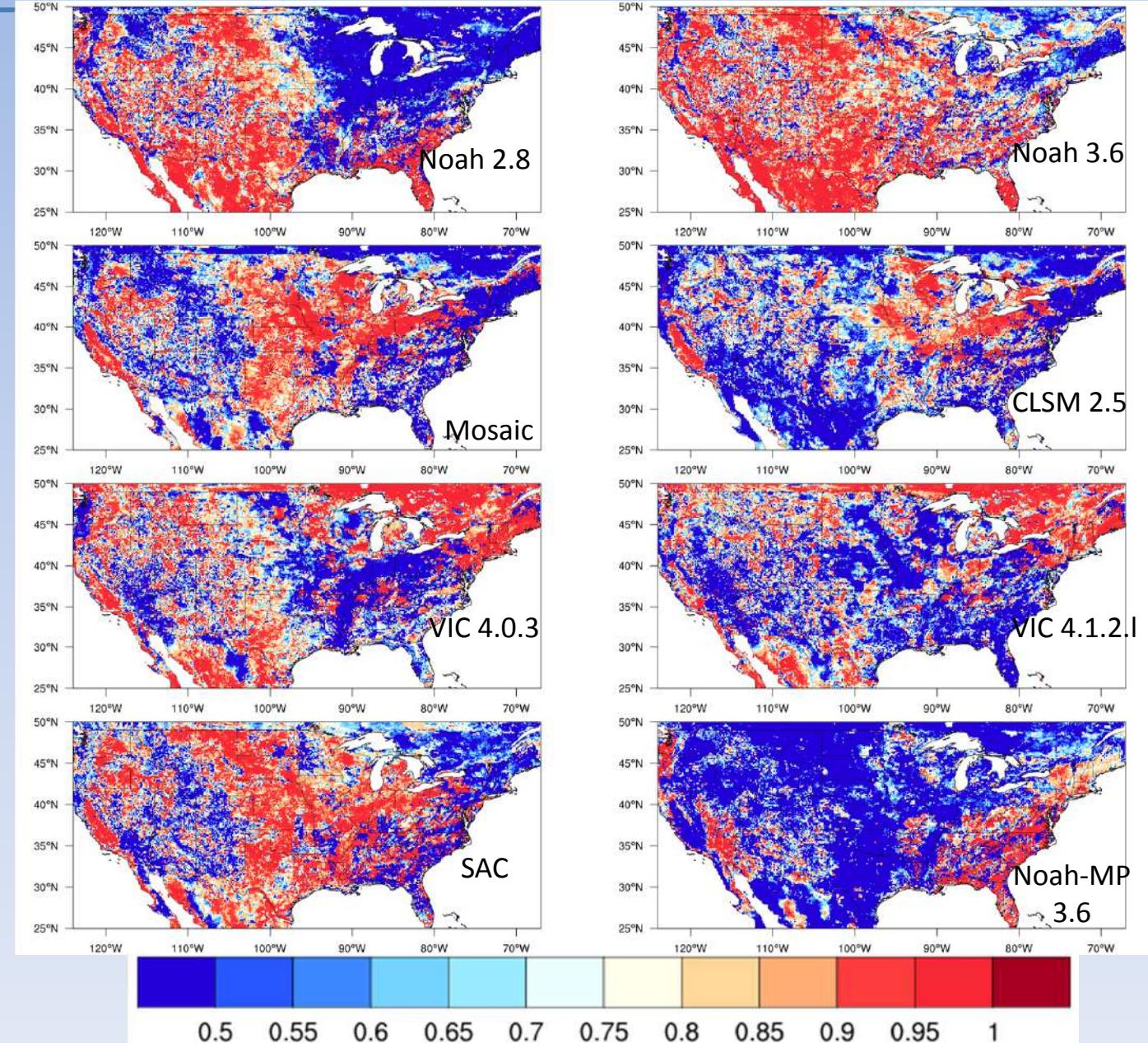


# Daily factor loading of only driest 5<sup>th</sup> percentile

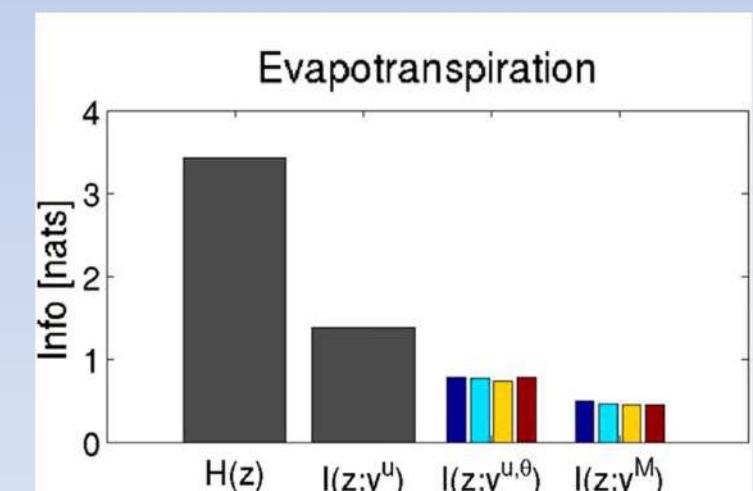
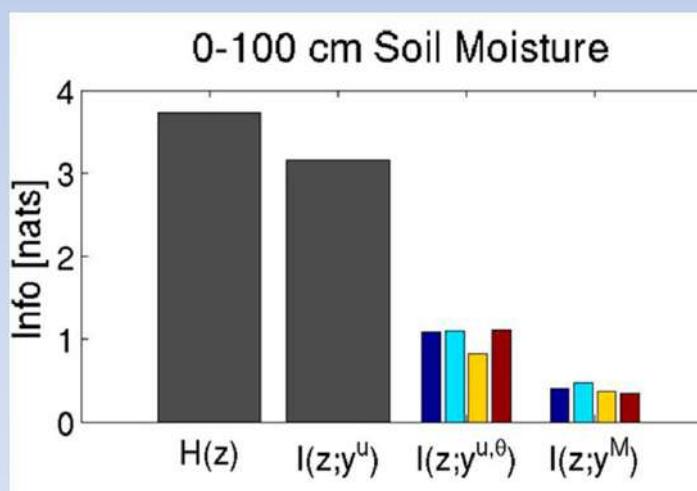
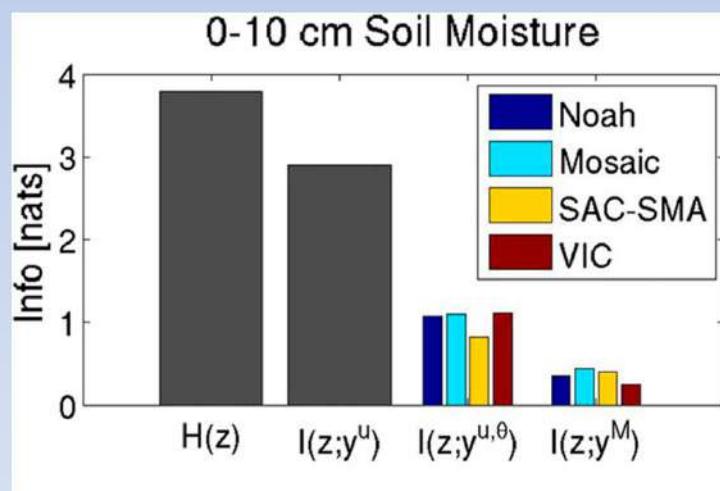
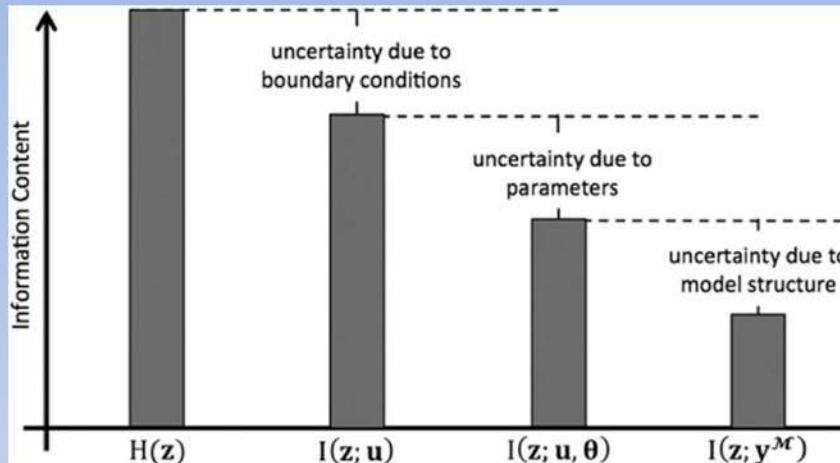
Data selection is conducted grid box by grid box. For the 8 models, if any of them have percentile value  $\leq 0.05$ , then the percentile outputs of the 8 models are selected. This means that the record number of selected data are different among the NLDAS grid boxes. Factor analysis is conducted if the record number of data is  $\geq 30$ . For a grid box, at least one value of percentile is less than or equal to 0.05 for a selected day.

We see much bigger differences than the full distribution.

5<sup>th</sup> percentile or drier = D3 or D4 drought



# Model physics vs. parameters and forcing



Nearing, Grey S., David M. Mocko, Christa D. Peters-Lidard, Sujay V. Kumar, and Youlong Xia, 2016:  
Benchmarking NLDAS-2 Soil Moisture and Evapotranspiration to Separate Uncertainty Contributions  
Journal of Hydrometeorology, 17:3, 745-759 , DOI: <http://dx.doi.org/10.1175/JHM-D-15-0063.1>.

# Summary and next steps

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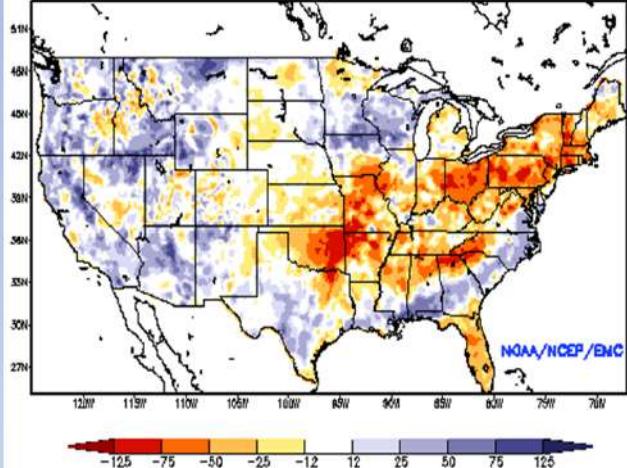
- New models being considered for NLDAS-3 have very similar behavior to each other, with slight improvements in soil moisture and runoff.
- Schemes with groundwater may help improve representation of drought recovery
- Coupling between groundwater and 1-m soil moisture may be too strong to represent drought severity (e.g., 2011)
- For soil moisture monitoring, biggest information loss is with forcing and parameters not physics—THEREFORE, must focus on updating NLDAS-3 forcing and parameters

# Backup slides

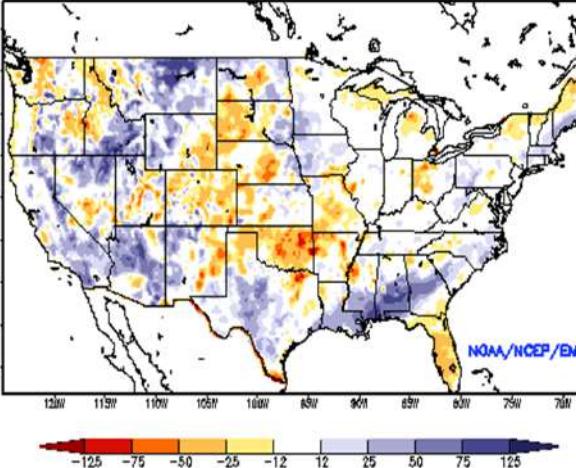
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# Current Operational NLDAS Drought Monitor: Top 1m soil moisture anomalies for three models and their ensemble mean

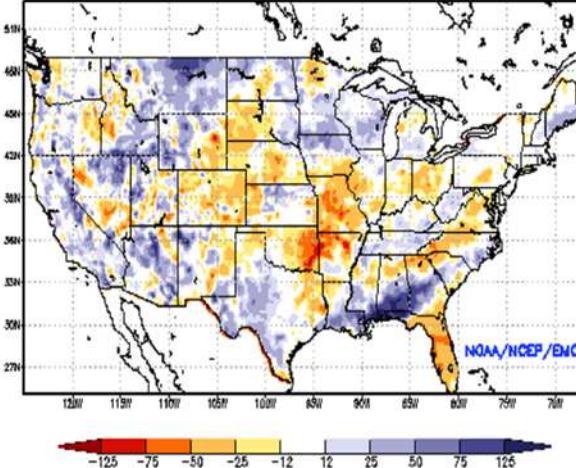
NASA Mosaic – Current Top 1M Soil Moisture Anomaly (mm)  
Valid: JAN 03, 2017



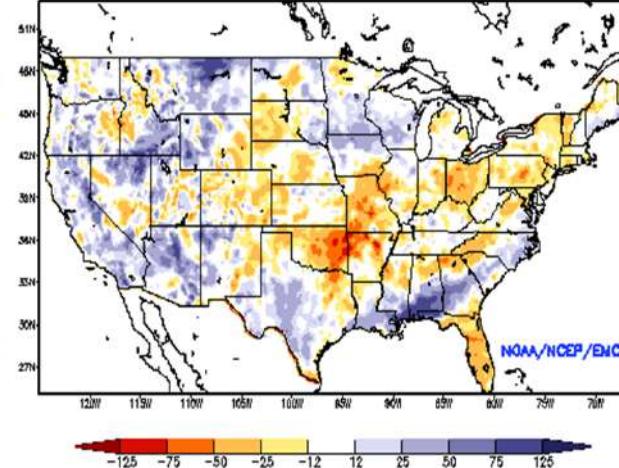
NCEP Noah – Current Top 1M Soil Moisture Anomaly (mm)  
Valid: JAN 03, 2017



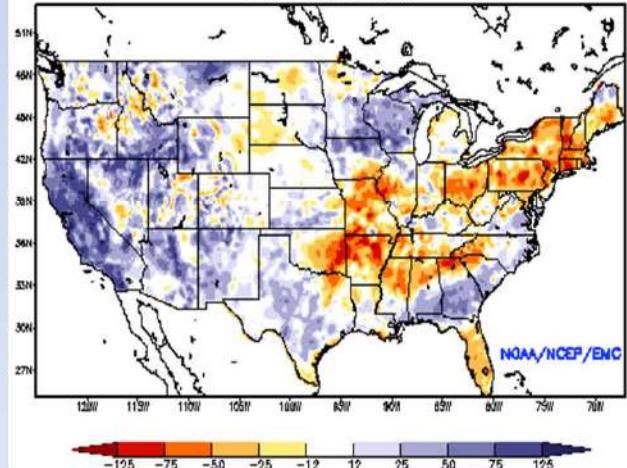
Princeton VIC – Current Top 1M Soil Moisture Anomaly (mm)  
Valid: JAN 03, 2017



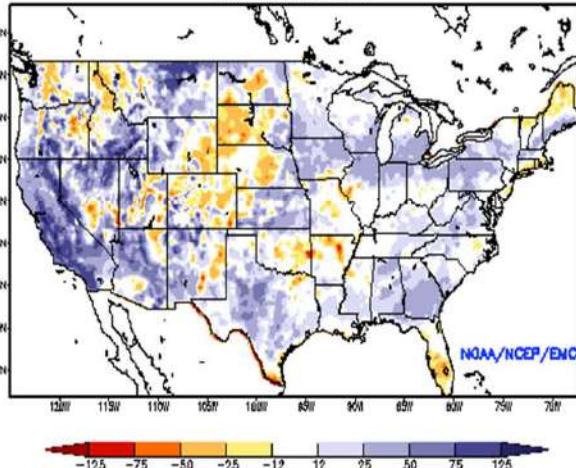
Ensemble-Mean – Current Top 1M Soil Moisture Anomaly (mm)  
NCEP NLDAS Products Valid: JAN 03, 2017



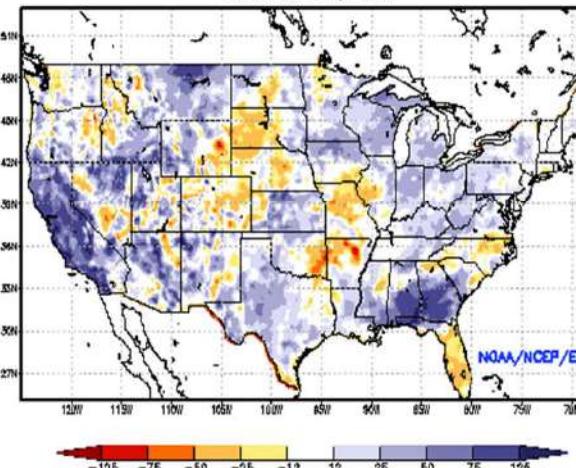
NASA Mosaic – Current Top 1M Soil Moisture Anomaly (mm)  
Valid: JAN 24, 2017



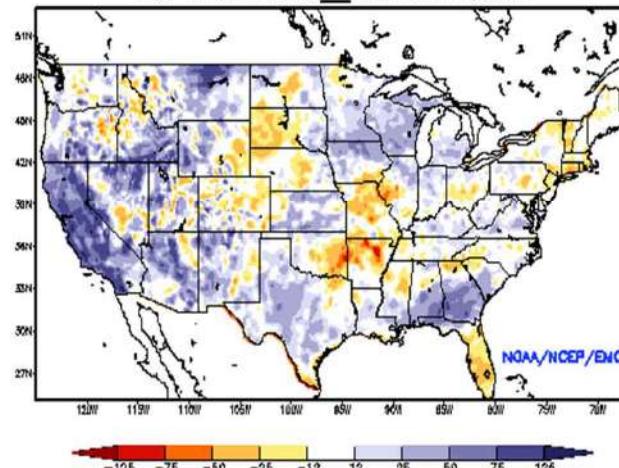
NCEP Noah – Current Top 1M Soil Moisture Anomaly (mm)  
Valid: JAN 24, 2017



Princeton VIC – Current Top 1M Soil Moisture Anomaly (mm)  
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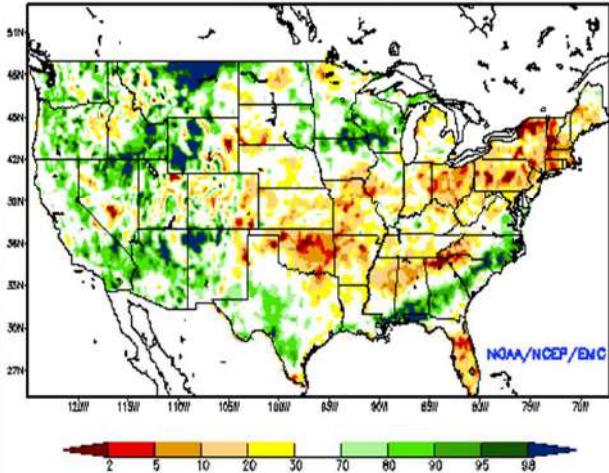


Ensemble-Mean – Current Top 1M Soil Moisture Anomaly (mm)  
NCEP NLDAS Products Valid: JAN 24, 2017

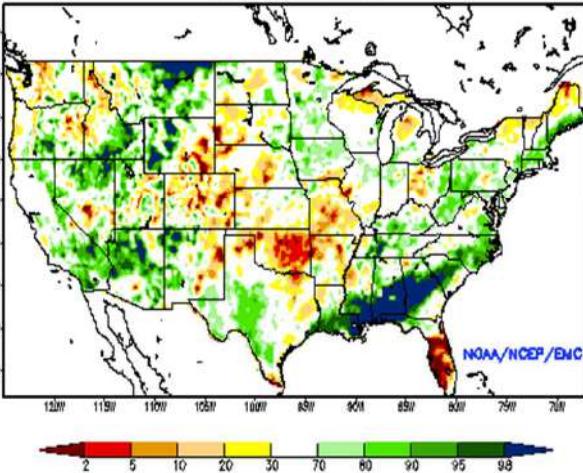


# Current Operational NLDAS Drought Monitor: Top 1m soil moisture percentiles for three models and their ensemble mean

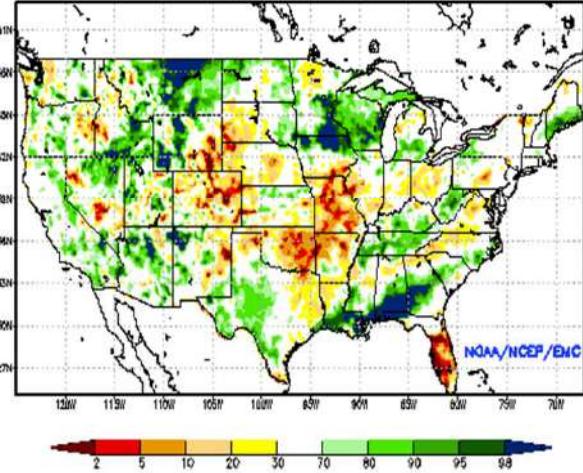
NASA Mosaic - Current Top 1M Soil Moisture Percentile  
Valid: JAN 03, 2017



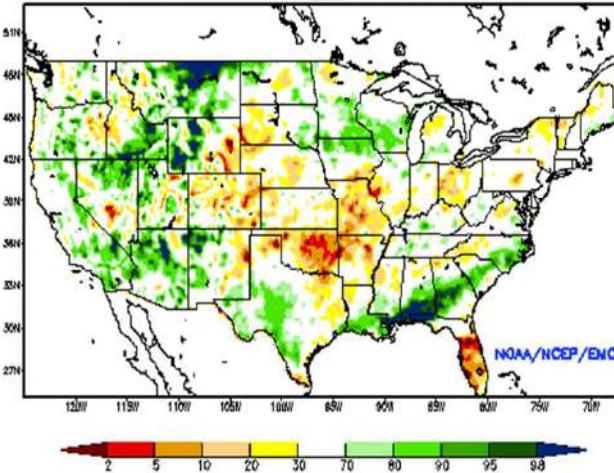
NCEP Noah - Current Top 1M Soil Moisture Percentile  
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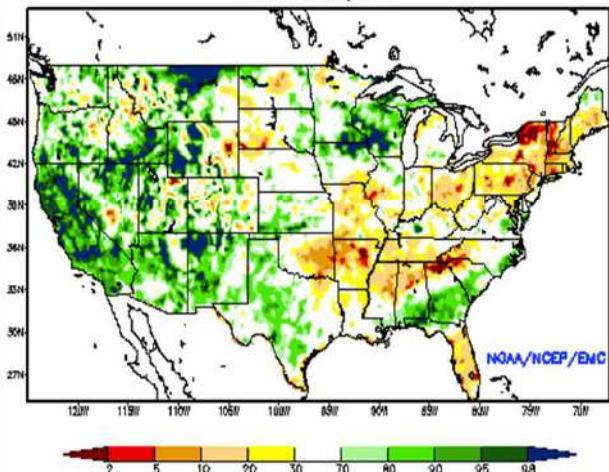
Princeton VIC - Current Top 1M Soil Moisture Percentile  
Valid: JAN 03, 2017



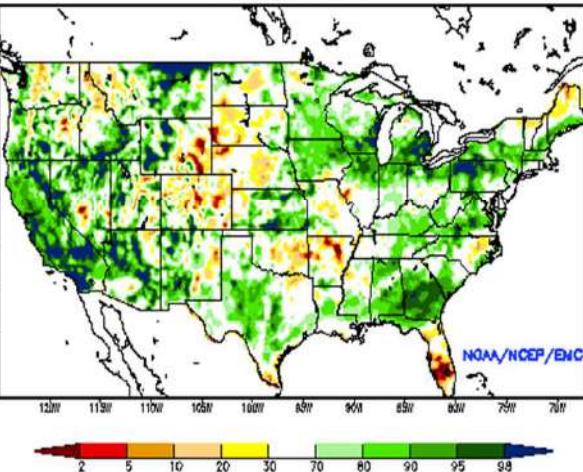
Ensemble-Mean - Current Top 1M Soil Moisture Percentile  
NCEP NLDAS Products Valid: JAN 03, 2017



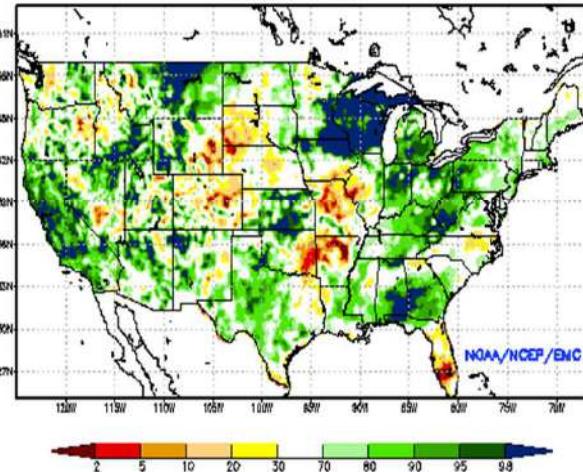
NASA Mosaic - Current Top 1M Soil Moisture Percentile  
Valid: JAN 24, 2017



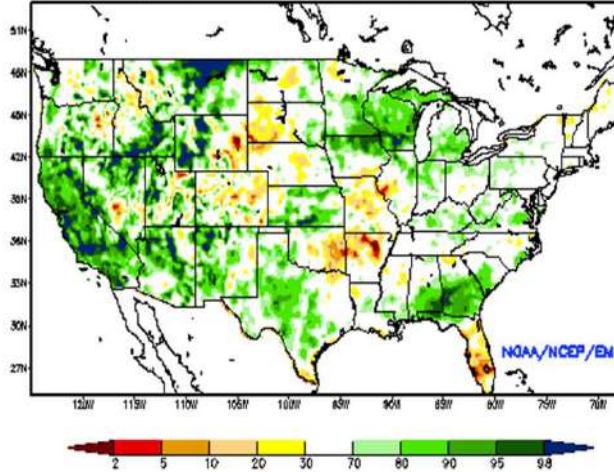
NCEP Noah - Current Top 1M Soil Moisture Percentile  
Valid: JAN 24, 2017



Princeton VIC - Current Top 1M Soil Moisture Percentile  
Valid: JAN 24, 2017



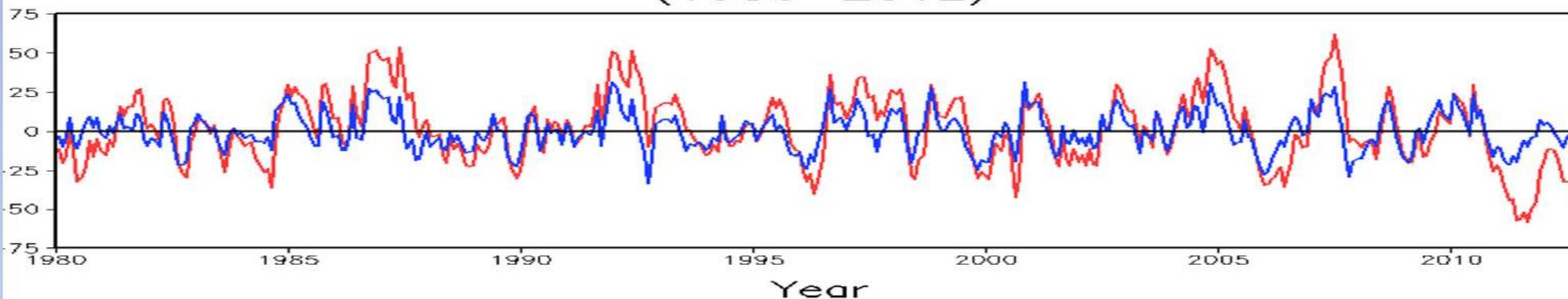
Ensemble-Mean - Current Top 1M Soil Moisture Percentile  
NCEP NLDAS Products Valid: JAN 24, 2017



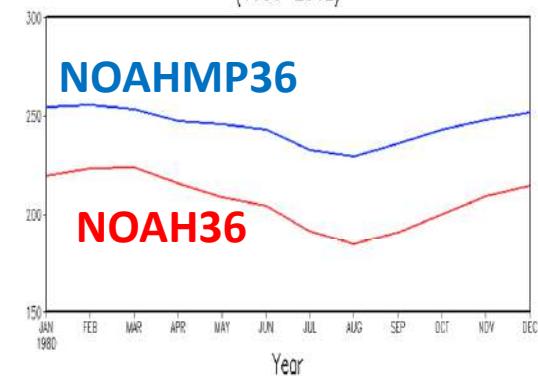
# Region [105-95°W, 25-38°N]

GW modulates soil moisture and has small anomaly amplitude

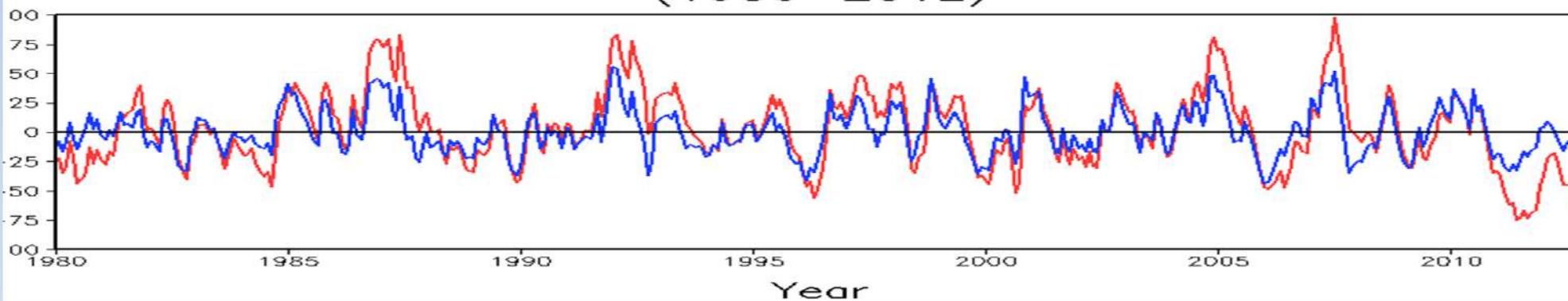
(a) Top 1m Soil Moisture Anomaly (mm)  
(1980–2012)



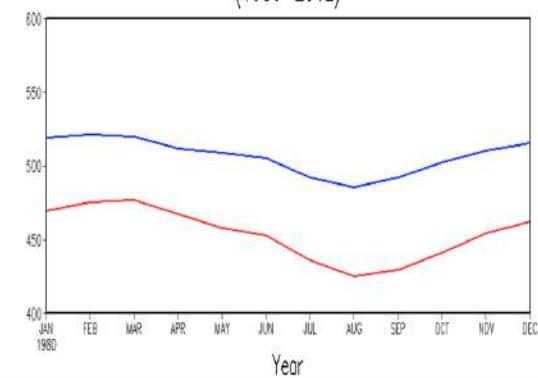
(a) Top 1m Soil Moisture Climatology (mm)  
(1980–2012)



(b) Top 2m Soil Moisture Anomaly (mm)  
(1980–2012)



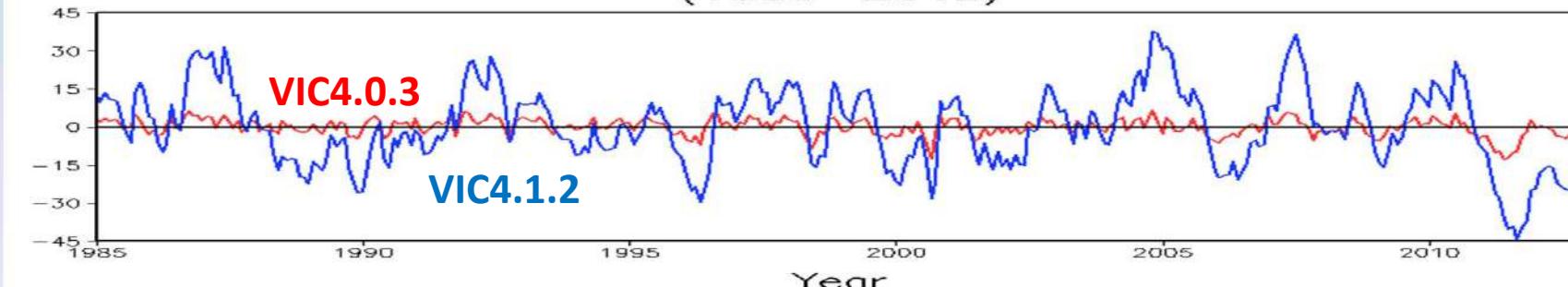
(b) Top 2m Soil Moisture Climatology (mm)  
(1980–2012)



Top 1m Soil Moisture (mm)  
(1985–2012)

VIC4.0.3

VIC4.1.2



VIC4.0.3 has small amplitude and is drier than VIC4.1.2. The reason is the two VIC model soil water distribution. VIC4.0.3 second soil layer has much less water than VIC4.1.2 although there is more water in third soil layer.

# California winter drought reduction 2016-2017

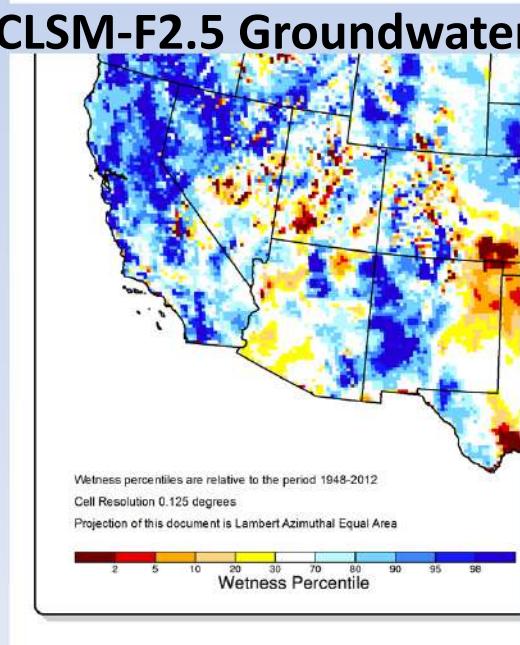
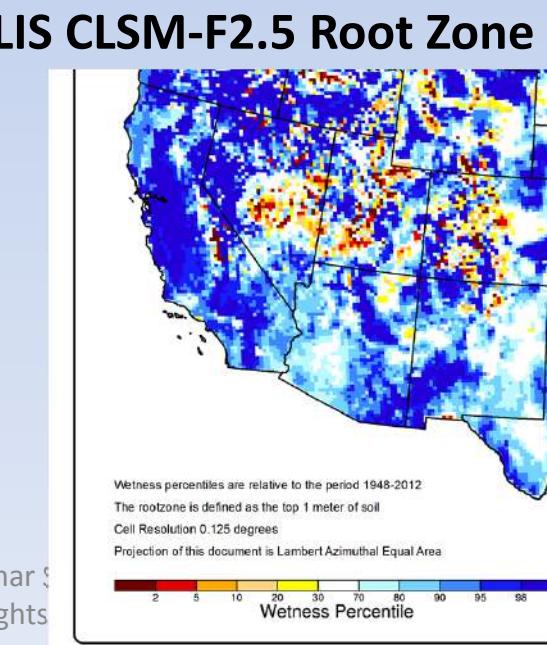
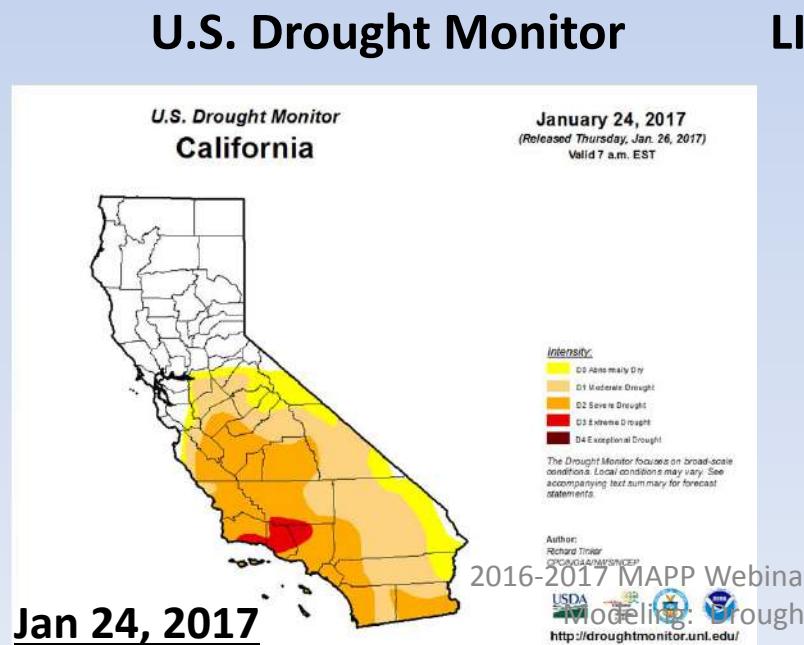
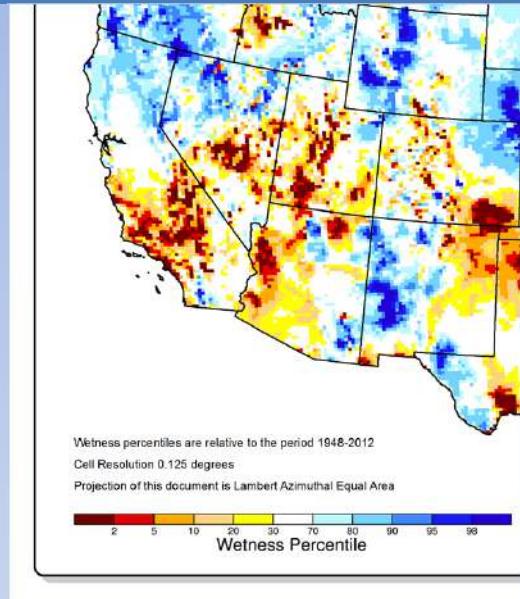
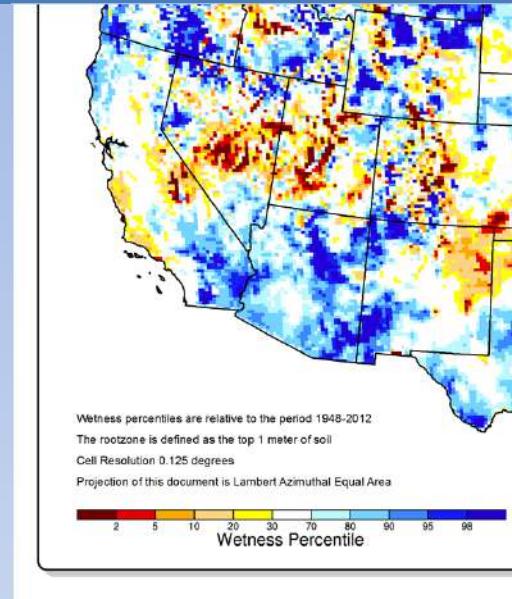
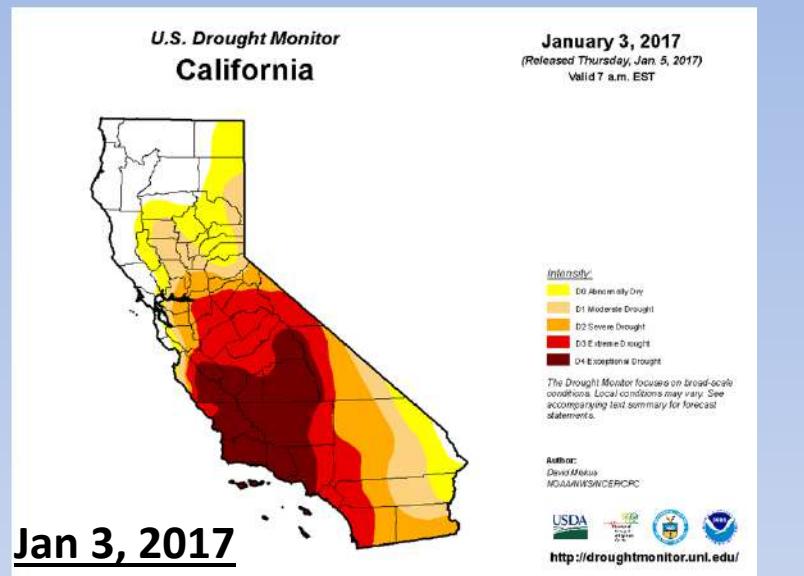
Same figures, but for CLSM-F2.5.

CLSM does not show any drought in GWS.

This run is with the 2-meters added to the bedrock depth.

Perhaps a deeper depth to bedrock is needed, as the column may be wetting too soon compared to the slower Noah-MP GWS.

3/27/17



# California winter drought reduction 2016-2017

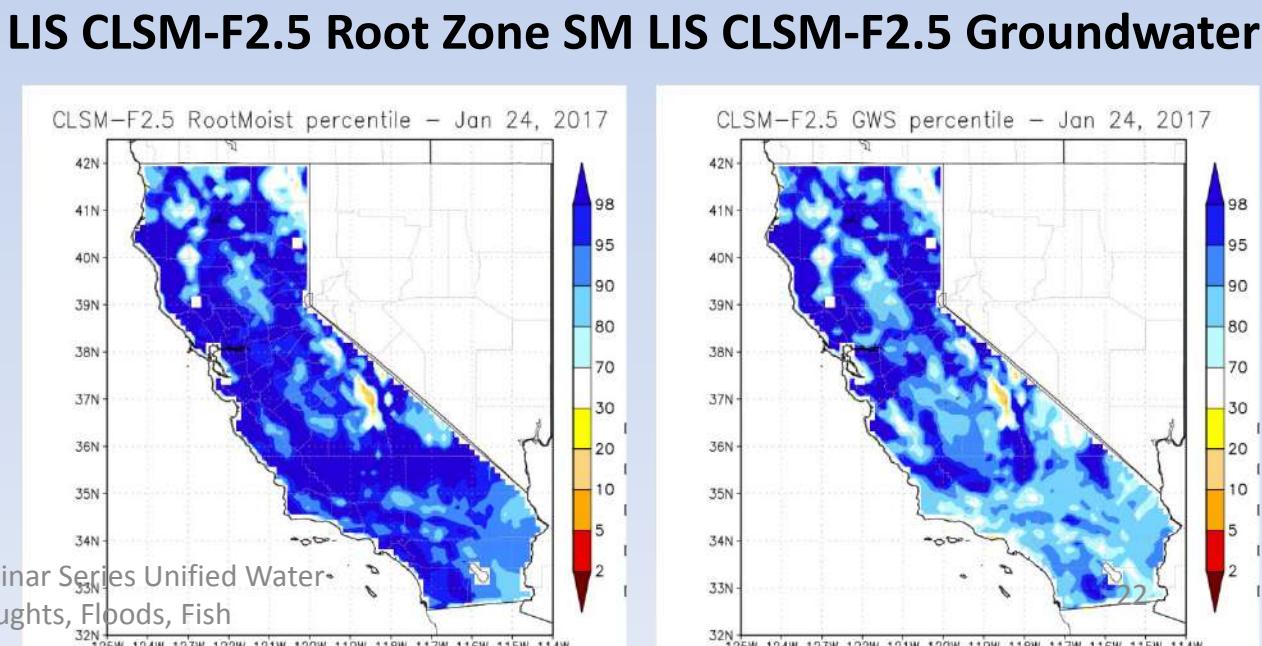
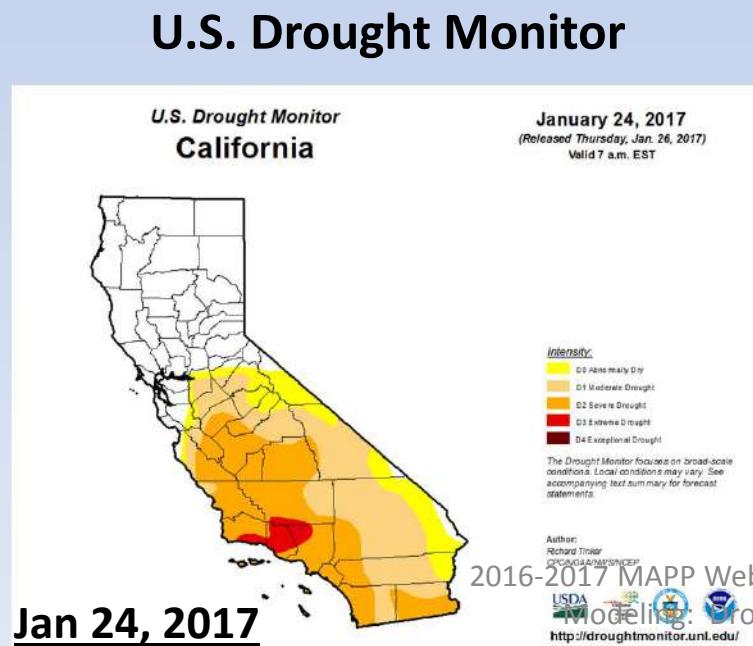
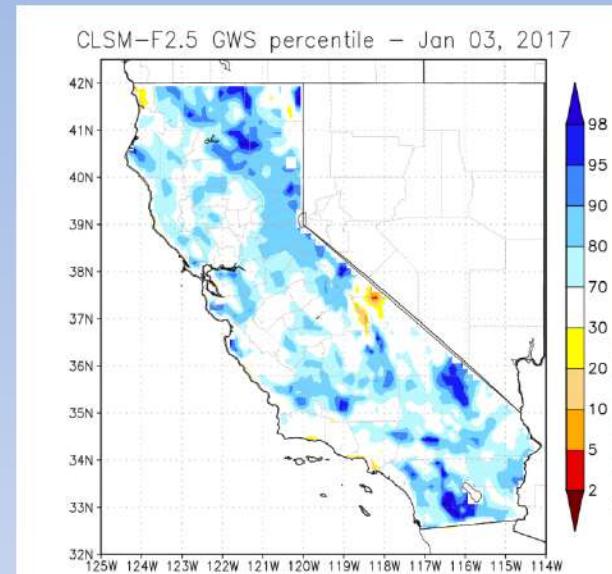
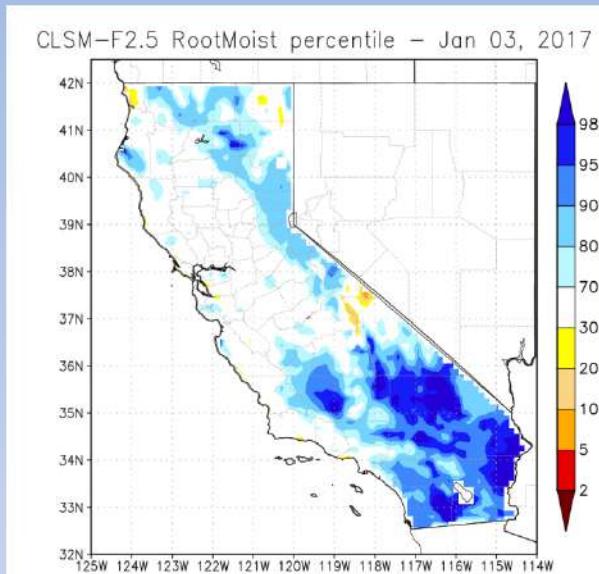
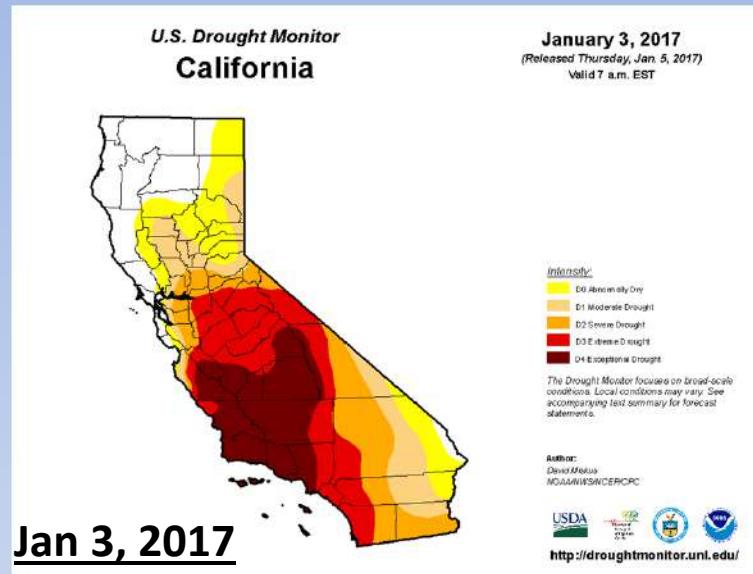
Same figures, but for  
CLSM-F2.5.

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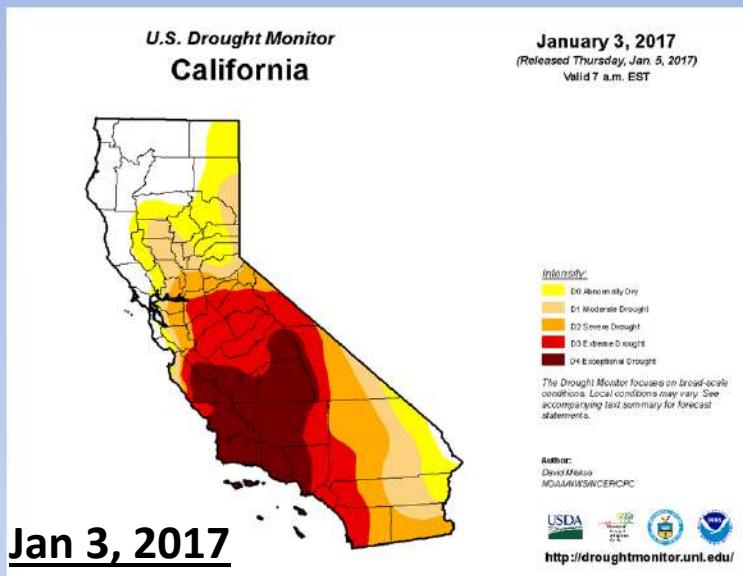
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GWS.

3/27/17

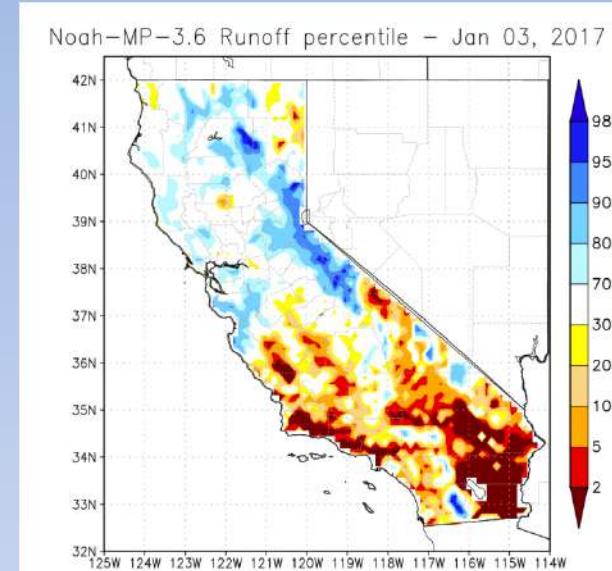


# California winter drought reduction 2016-2017

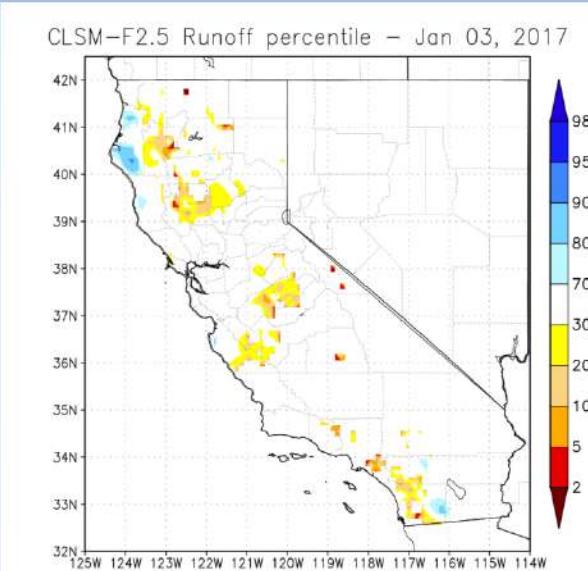
Same figures, but for  
Total Runoff.



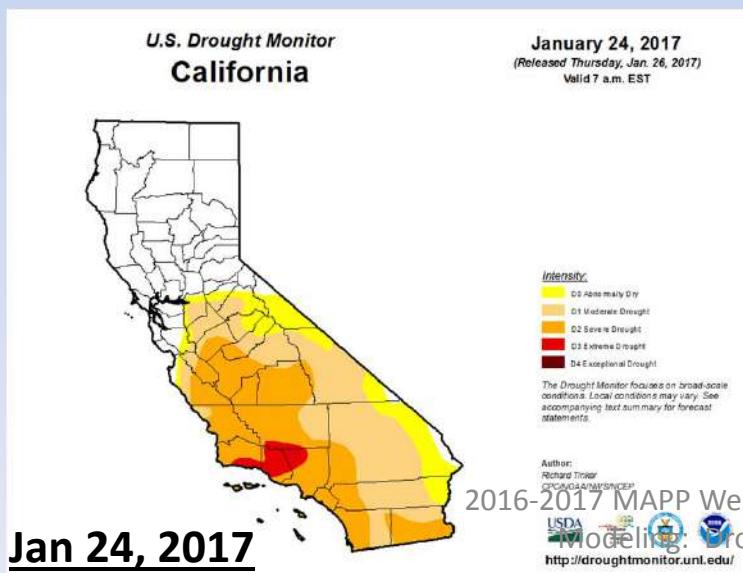
**U.S. Drought Monitor**



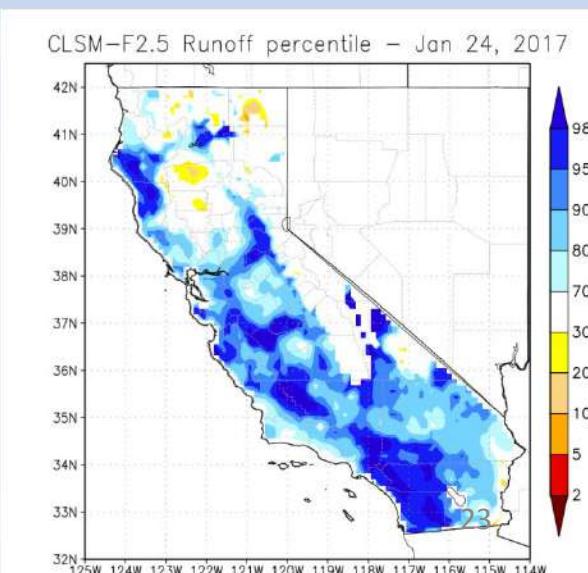
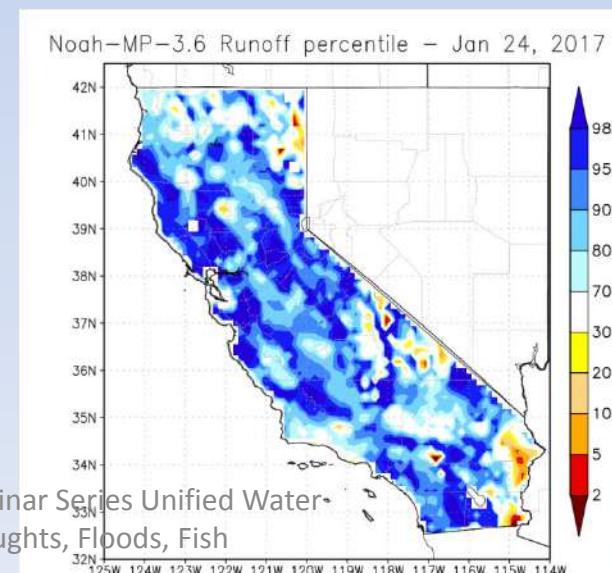
**LIS Noah-MP Runoff**



**LIS CLSM-F2.5 Runoff**

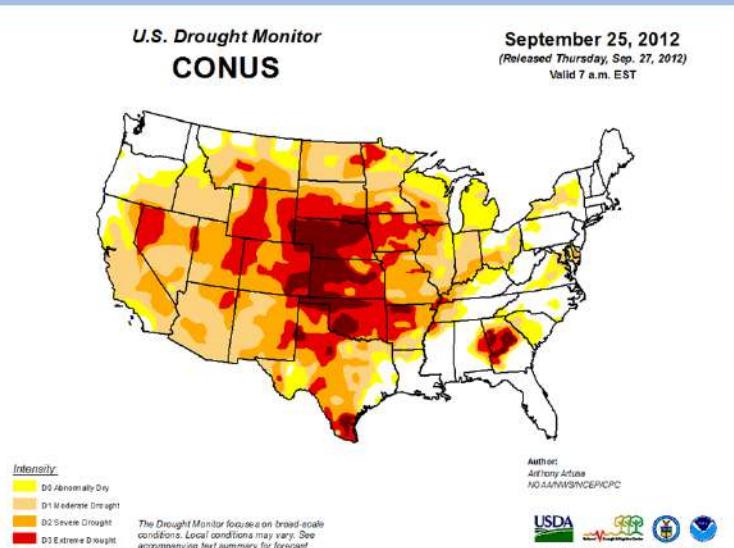
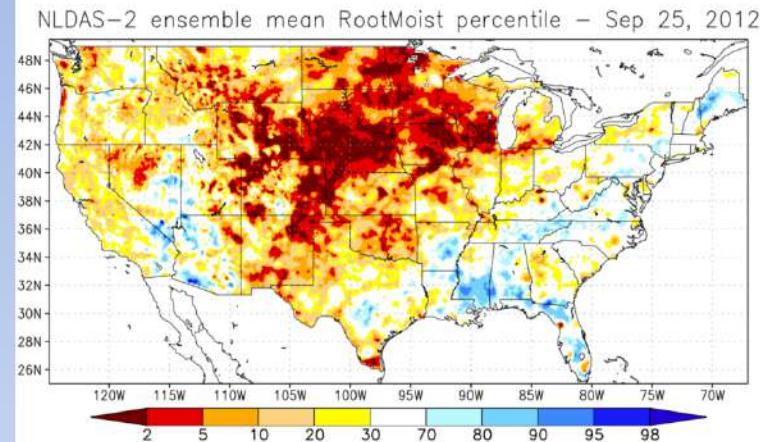


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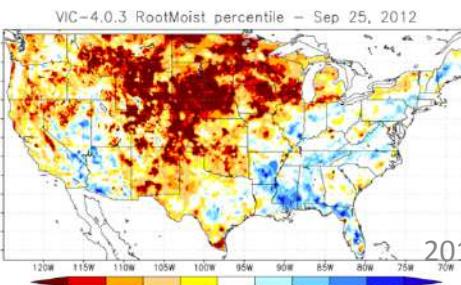
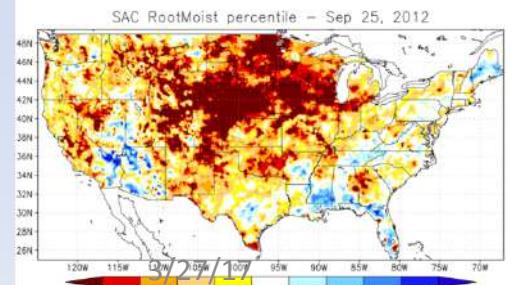
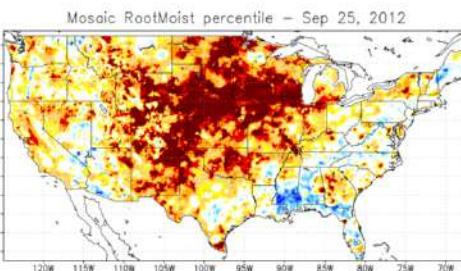
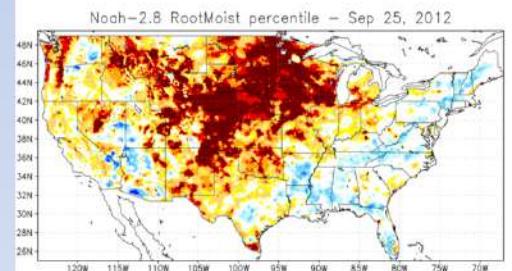
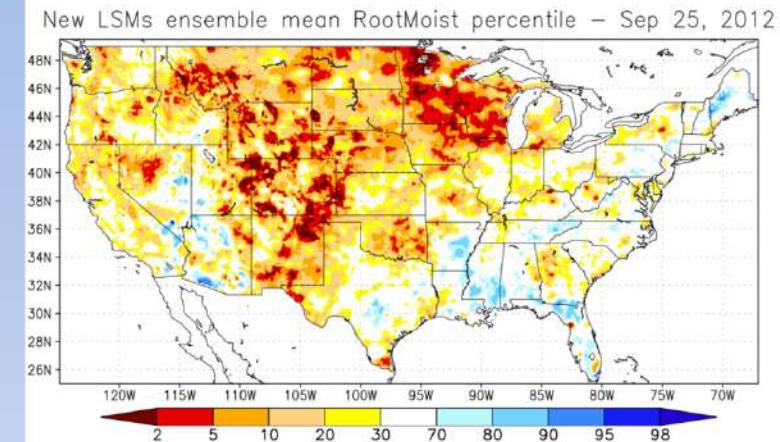


# Sep 25, 2012 – Great Plains Drought

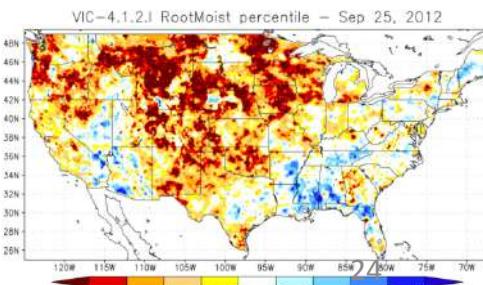
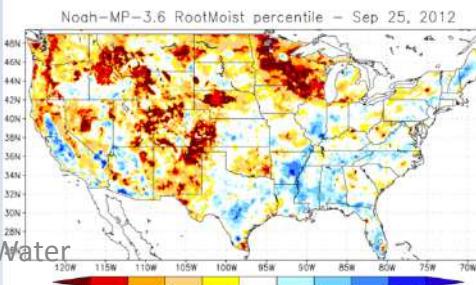
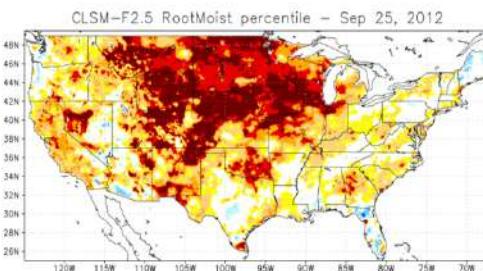
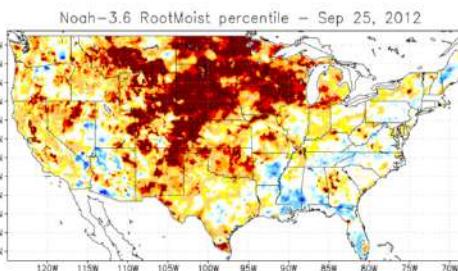
## NLDAS-2 operational LSMs



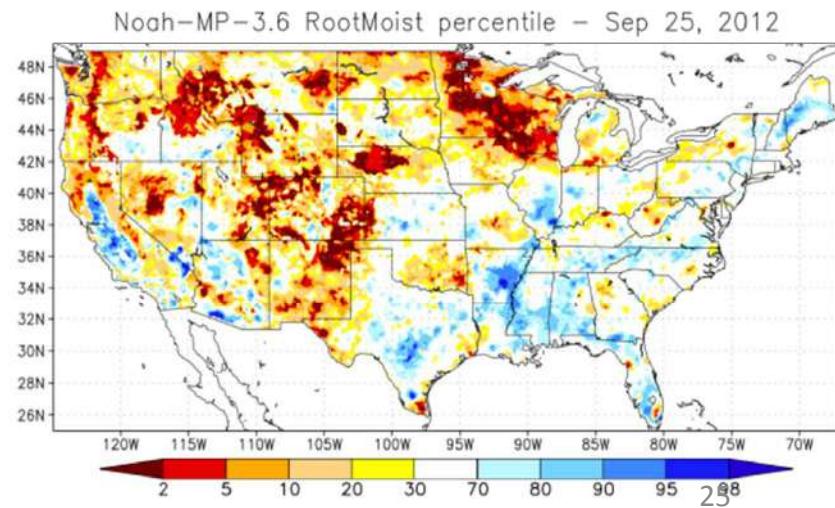
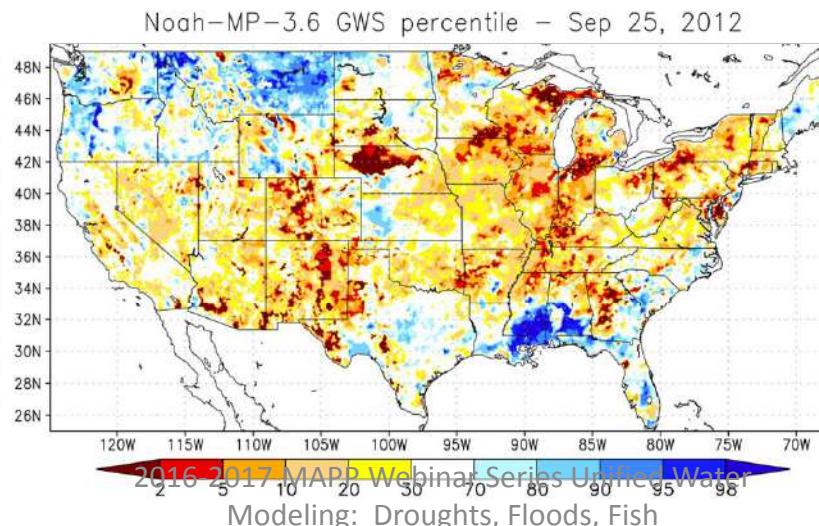
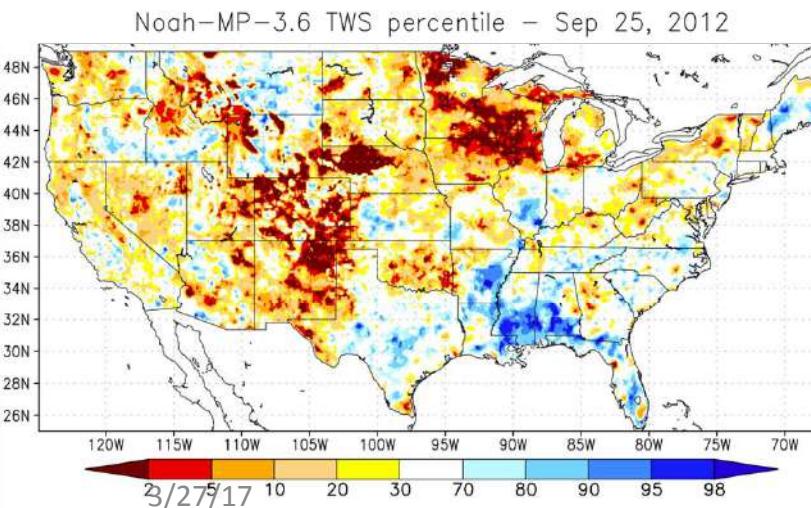
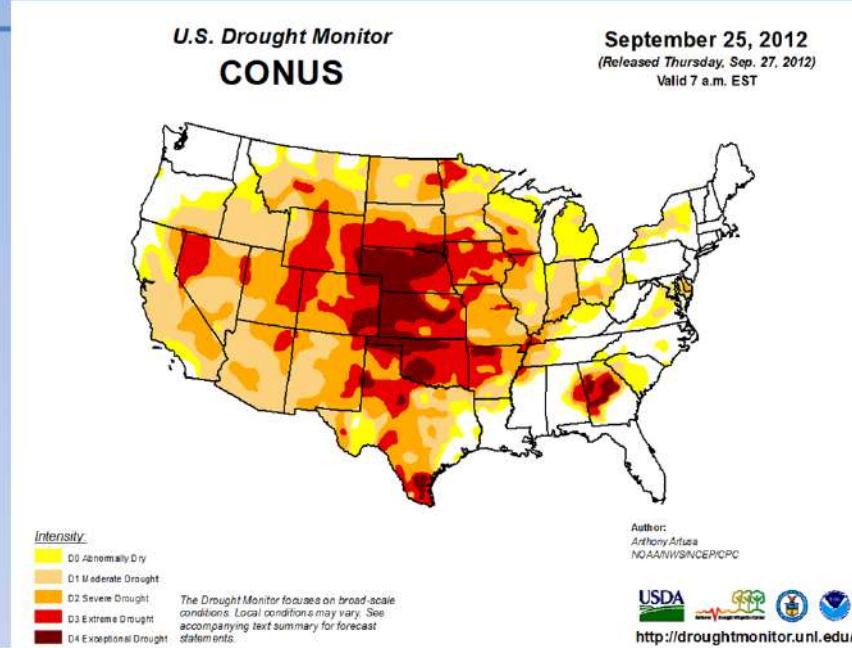
## LIS LSMs for next phase



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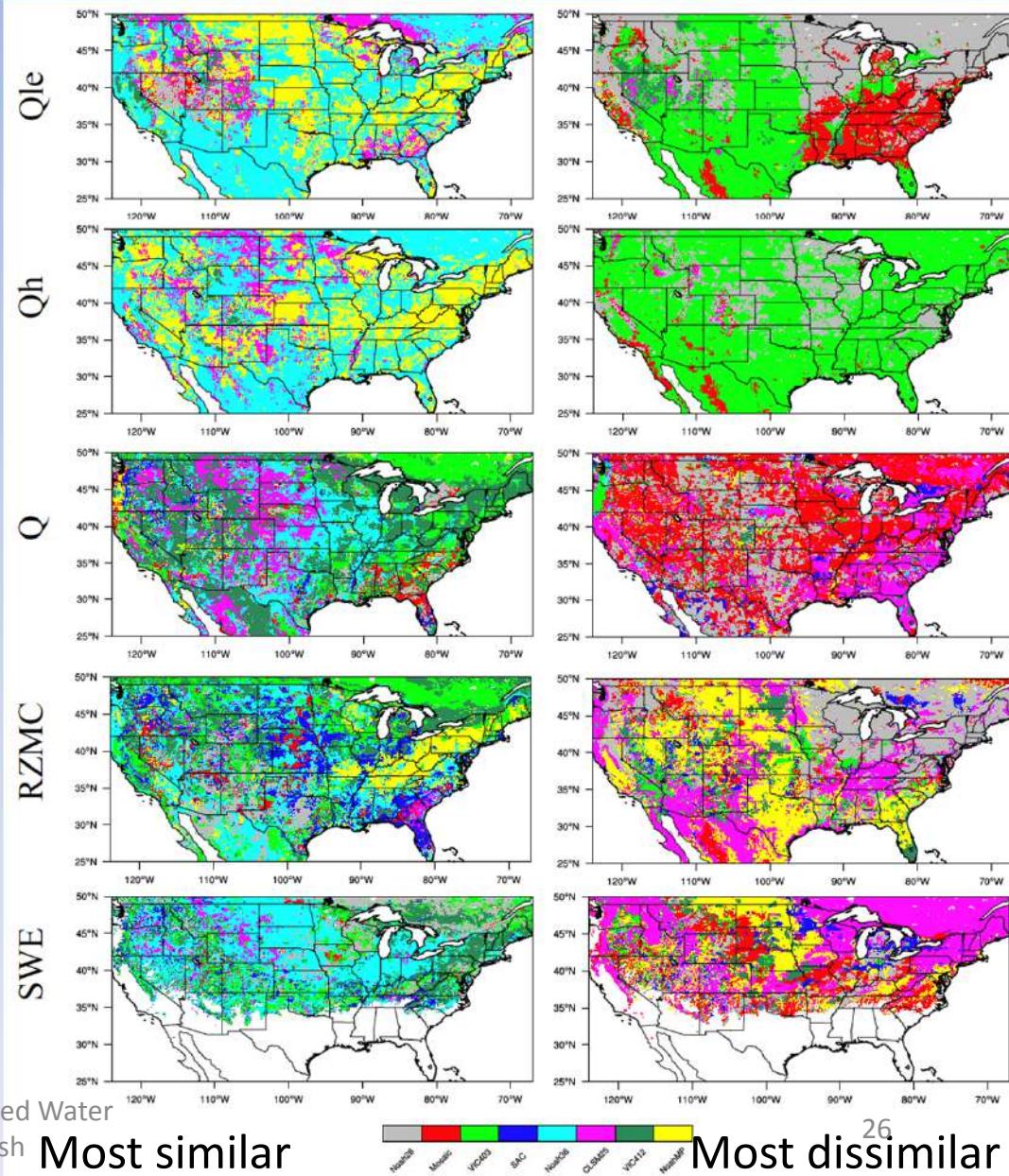
# Sep 25, 2012 – Great Plains Drought



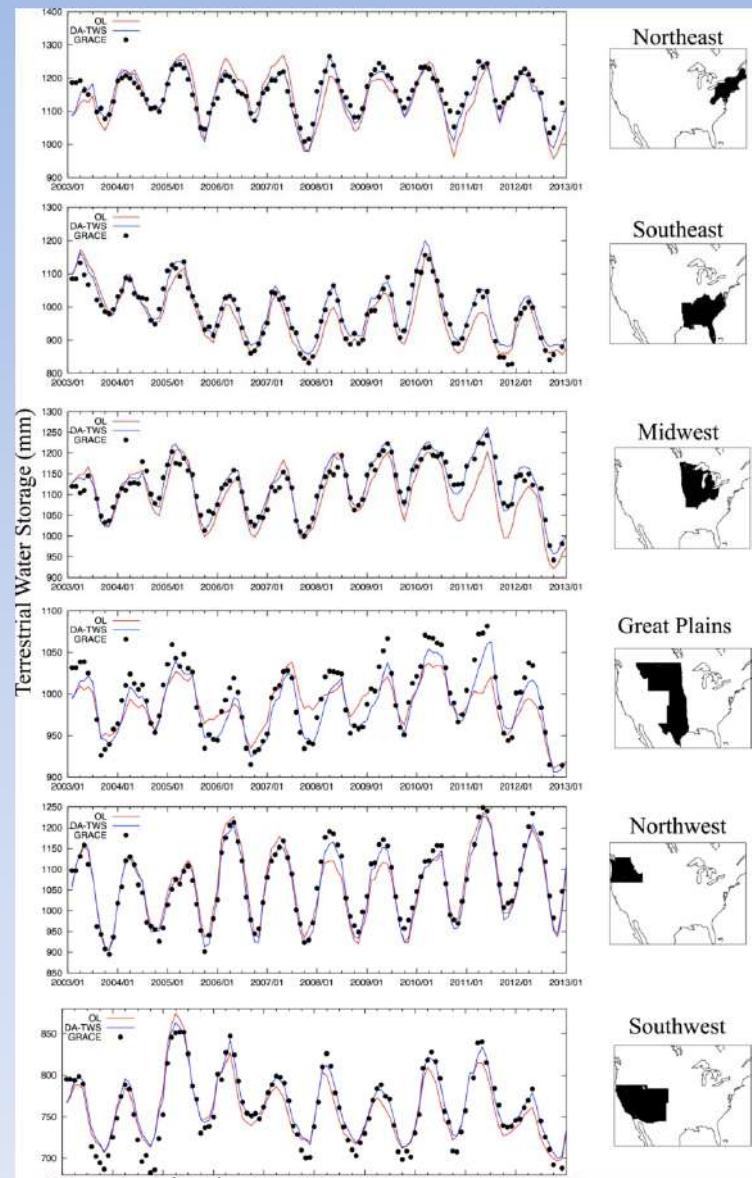
# Similarity result from paper

The 8 LSMs under evaluation (the 4 operational NLDAS-2 LSMs and 4 of the LIS LSMs) were included in a formal similarity assessment to assess their utility to the ensemble. The runoff estimates from the LSMs were shown to be most dissimilar, and the soil moisture shown to be the most similar.

The figure on the right show which of the 8 LSM is the most similar (left column) and the most dissimilar (right column) to the ensemble, for the latent (Qle) and sensible (Qh) heat fluxes, runoff (Q), root zone soil moisture (RZMD), and snow-water equivalent (SWE).



# Sujay GRACE DA paper

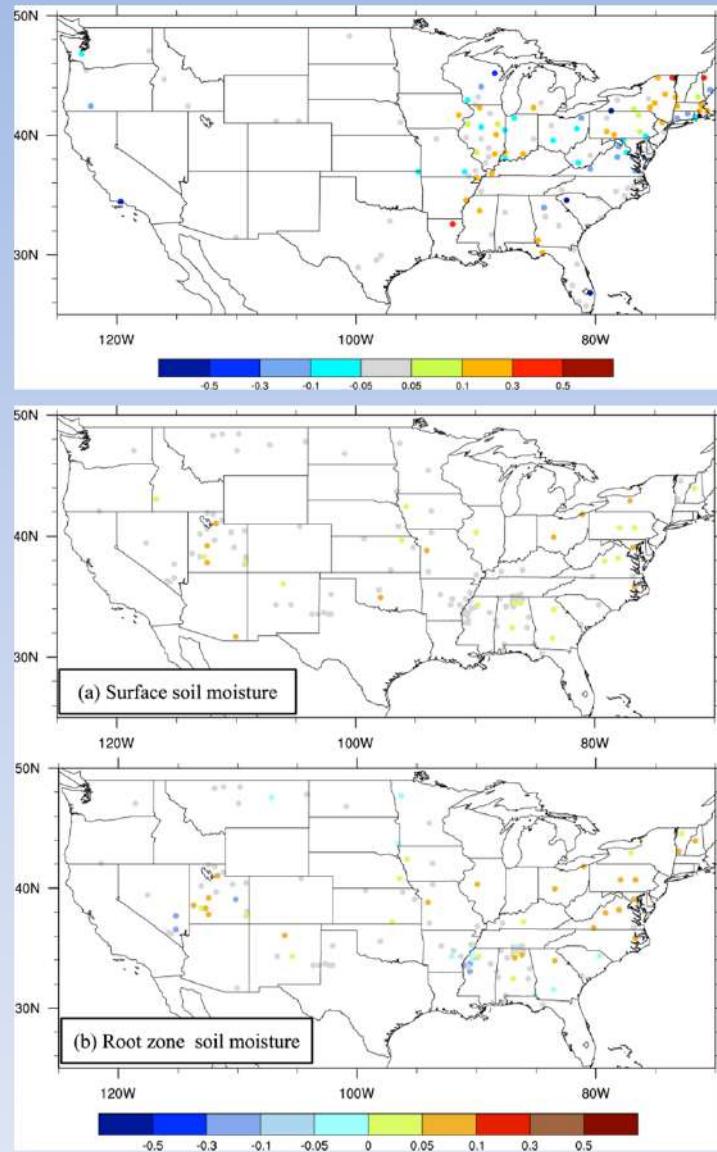


Data assimilation of GRACE in the CLSM-F2.5 was compared to a simulation without DA.

The left figure shows the TWS time series for various CONUS regions for GRACE against an Open Loop (OL; no day) run and the DA run.

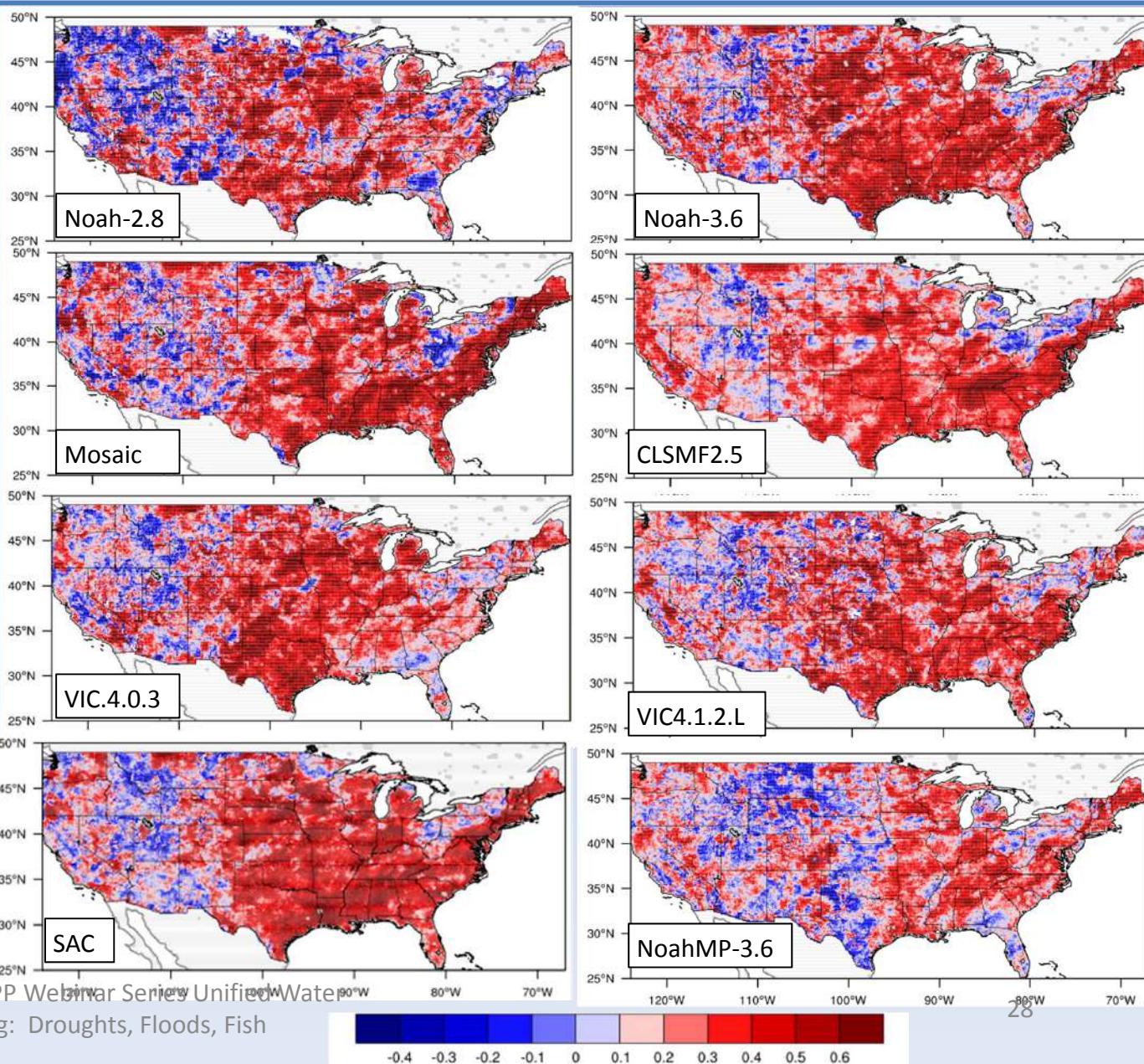
The upper right panel shows the change in the anomaly correlation of simulated groundwater against USGS well observations. Warm colors indicate sites with improvement of DA over OL – while cool colors indicate degradation.

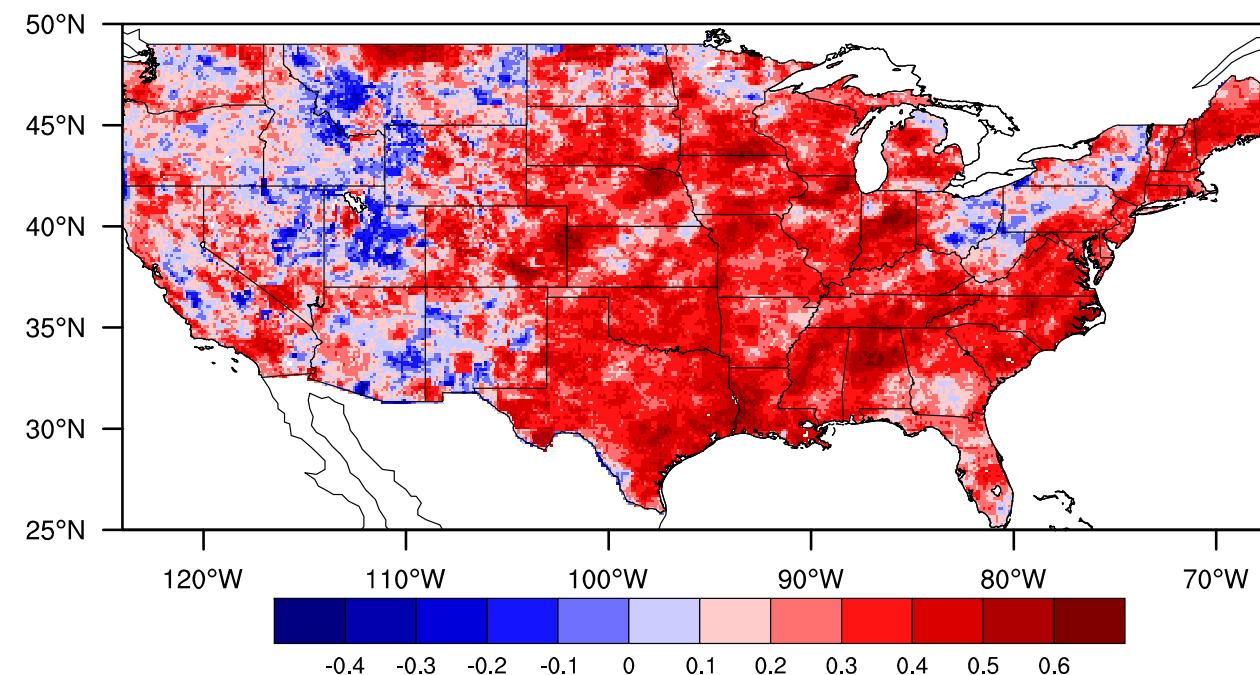
The lower right panels show the same change in anomaly correlation, but for surface and root zone soil moisture against in situ SCAN observations.



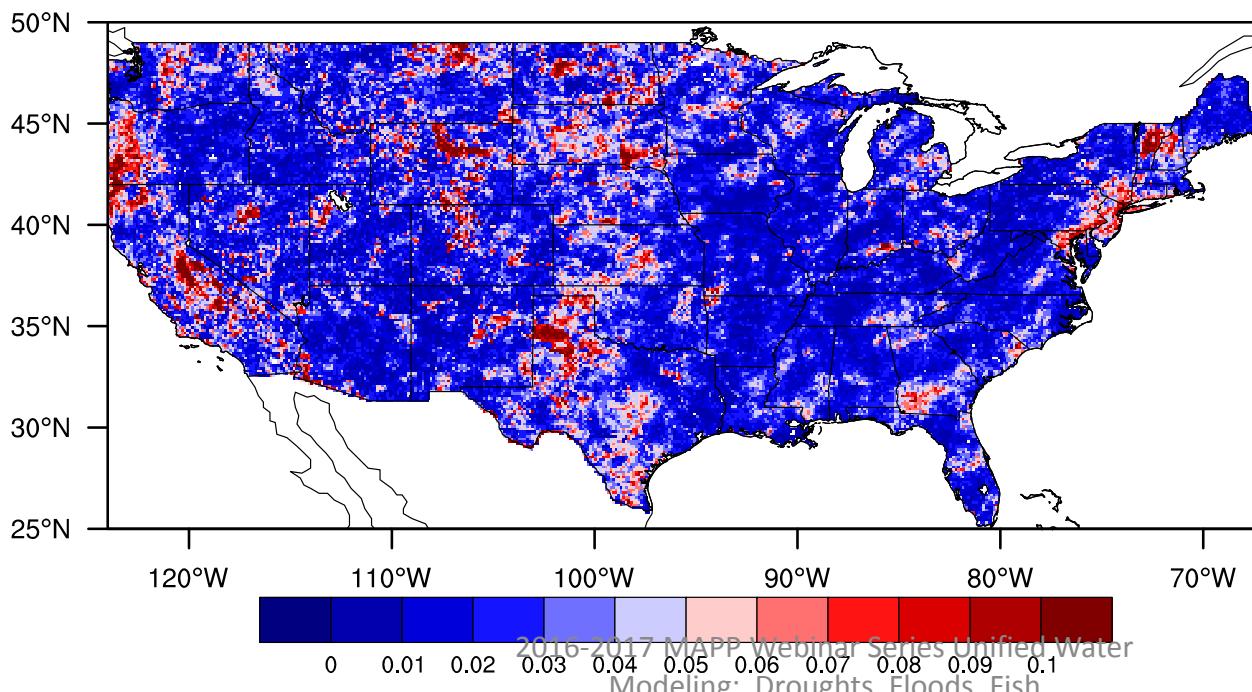
# Correlation of USDM and top 1-m SM percentiles

Using LVT, the correlation of digitized USDM drought categories and of drought categories from the top 1-m soil moisture percentiles of each LSM were calculated.

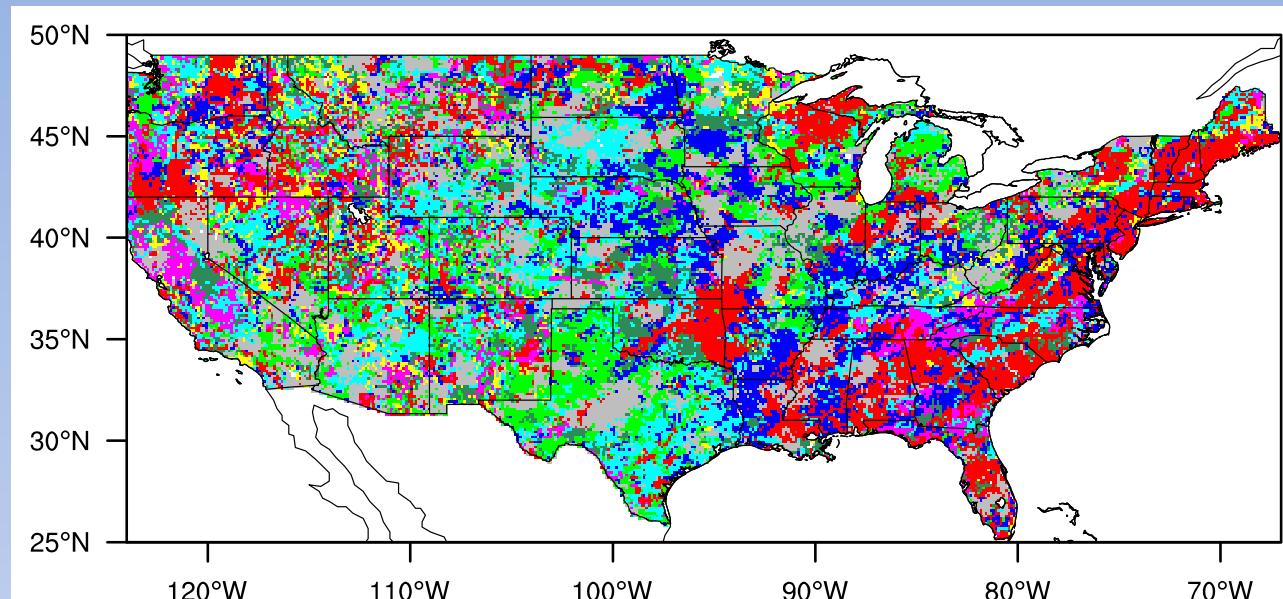




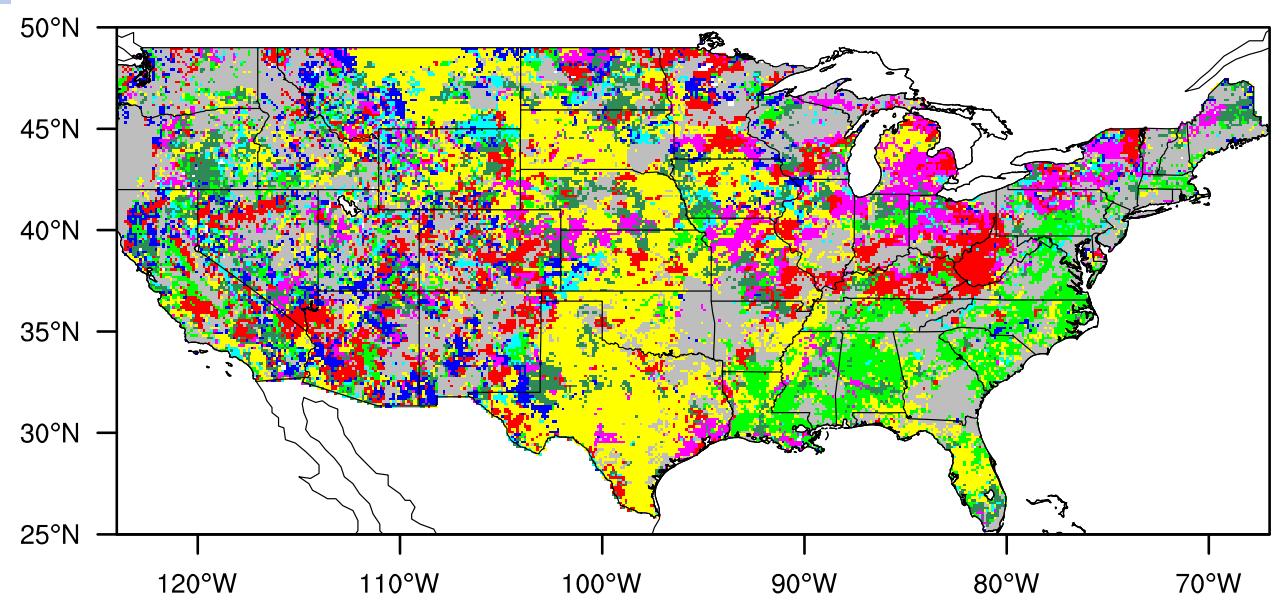
Mean of correlations between each LSM-based drought estimate and the USDM drought estimate



Variance in the correlations between each LSM-based drought estimate and the USDM drought estimate



Model with the best correlation to the USDM



Model with the worst correlation to the USDM

Noah28      Mosaic      2016 VIC403      SAC      Noah36      CLSM25      VIC412      NoahMP

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# HyMAP vs. NLDAS router

Both the HyMAP router (Getirana et al., 2012) and the NLDAS router (Lohmann et al., 2004) are included within LIS. However, the NLDAS router is tied to the current NLDAS grid, while HyMAP supports finer-scale and global domains. Also, HyMAP provides river depth as well as discharge, considers floodplains among many other physics upgrades.

